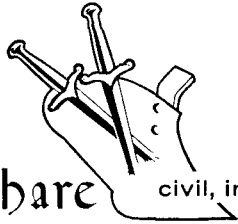


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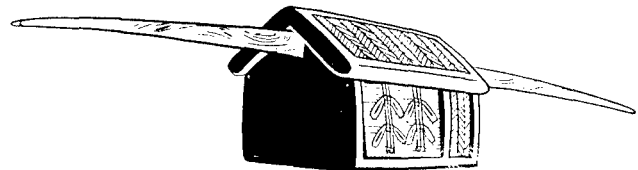
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PNE-905

NUCLEAR EXPLOSIONS - PEACEFUL  
APPLICATIONS (TID-4500)

PROJECT PALANQUIN

PRESHOT GEOLOGIC AND ENGINEERING PROPERTIES INVESTIGATIONS

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June 1967

## ABSTRACT

A comprehensive geologic and engineering investigation was undertaken at the site on Pahute Mesa selected for the Palanquin event, a cratering experiment conducted in dry rock at the U. S. Atomic Energy Commission's Nevada Test Site.

Foundation conditions were determined by means of five borings satellitic to the emplacement hole: a 5-1/2-inch-diameter boring to a depth of 351.0 feet and four NX-size holes ranging in depth from 199.2 to 270.5 feet. The site is blanketed by a thin soil cover ranging in thickness from 4 to 13 feet, overlying a 575-foot-thick section of the Ribbon Cliff formation. The uppermost flow of this formation is porphyritic trachyte, which is at least 351 feet thick beneath the site. The Ribbon Cliff formation is immediately underlain by the vitric tuffs and welded tuffs of the Timber Mountain Tuff.

Although normally a competent material, the porphyritic trachyte is severely altered and decomposed within zones of intense fracturing related to faulting.

Subsurface data indicate the presence of a high-angle normal fault that strikes N27°E and dips 64 degrees to the northwest. This fault plane is enveloped by a zone of intense fracturing that is 73 feet thick. The base of this fracture zone parallels the fault plane and intersects the surface at a point 10 feet west of surface ground zero.

Field observations indicate that four high-angle joint sets are developed within the Ribbon Cliff formation--two major sets that have average strikes of N65°W and N55°E, and two minor sets that have average strikes of N16°W and N15°E. Low-angle bedding joints may be present locally. Joints of the dominant sets have an average spacing of less than 2 feet. Minor joint sets have spacings that vary from 3 to 10 feet. A comparison of surface observations with the results of a brief analysis of borehole photographs indicates a significant decrease in the frequency of joints with depth.

The average physical property values of the porphyritic trachyte are as follows: dry bulk specific gravity, 2.49; dry bulk density, 155 pcf; static unconfined compressive strength, 13,370 psi; modulus of elasticity,  $3.8 \times 10^6$  psi; and Poisson's ratio, 0.26.

The static unconfined compressive strength tends to increase with increasing density values. The average bulk density in the upper 100 feet was approximately 2 percent lower than average density values below a depth of 150 feet.

Geophysical logging consisting of density and caliper logs disclosed that the in situ density values obtained were not quantitatively comparable to values determined in the laboratory due to the erratic variation in borehole diameter indicated by the caliper logs. Although it was not possible to establish the trend of in situ density with depth above a depth of 150 feet due to the erratic

variations in borehole diameter, the trend of in situ density with depth below a depth of 150 feet appeared to approximate the trend indicated by physical tests, i.e. no major variation of density with depth.

Pressure tests indicated that permeability of the media at the Palanquin site was approximately  $35 \times 10^{-4}$  cm/sec near the surface and decreased to practically zero at a depth of 110 feet. No pressure test data were obtained between depths of 110 and 139.5 feet. Pressure test data obtained between depths of 139.5 and 203 feet were unreliable due to excessive head losses in the riser pipe. Between depths of 203 and 213 feet, the permeability was  $27 \times 10^{-4}$  cm/sec. No pressure test data were obtained below a depth of 213 feet.

## PREFACE

Project Palanquin was a cratering event conducted in Area 20 of the Nevada Test Site by the Lawrence Radiation Laboratory (LRL) for the U. S. Atomic Energy Commission. The U. S. Army Engineer Nuclear Cratering Group (NCG) participated in this experiment to determine the preshot geology and physical properties of the media. The information obtained augments data collected from previous high-explosive and nuclear cratering tests. This report presents the results of the preshot geological and engineering investigations of the Project Palanquin site.

The geological studies and field and laboratory investigations reported herein were conducted by the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the NCG. The site of the Palanquin event was selected on the basis of criteria designated by LRL and investigations conducted by the U. S. Geological Survey prior to February 1965.

The WES was requested in January 1965 to conduct preshot exploration of the Palanquin site. The drilling program, except for the calyx hole and LRL instrumentation holes, was under the direction of Mr. T. B. Goode, Soils Division. Cores from all holes drilled by WES were logged by Mr. Richard Hunt, Soils Division. General geologic observations were made by LLT R. C. Nugent and Mr. Hunt.

Personnel of the Concrete Division, WES, performed the physical tests and petrographic examination of core samples. The report was written by 1LT Nugent and Mr. F. E. Girucky, Soils Division. Minor modifications have been made subsequently by Dr. R. J. Lutton in preparing the report for publication. The investigations were conducted under the direction of Messrs. W. J. Turnbull, A. A. Maxwell, J. R. Compton, C. R. Kolb, W. B. Steinriede, Jr., and W. C. Sherman, Soils Division.

The Director of NCG during the preshot field investigations and the preparation of this report was LTC W. J. Slazak, CE. The Director of WES was COL J. R. Oswalt, Jr., CE. Technical Director of WES was Mr. J. B. Tiffany.



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# CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter
gallons	3.78533	liters

## CHAPTER 1

### INTRODUCTION

#### 1.1 PURPOSE

Project Palanquin was a cratering experiment conducted on Pahute Mesa at the U. S. Atomic Energy Commission's Nevada Test Site (NTS) (see Figure 1.1). The Palanquin experiment was conducted in dry rock, and it provided an opportunity for investigating the engineering properties of an explosion-produced crater in a medium other than basalt or alluvium.

#### 1.2 SCOPE

This report presents the results of the preshot geologic and engineering investigations conducted for Project Palanquin by the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Army Engineer Nuclear Cratering Group (NCG). The Palanquin site was selected by the Lawrence Radiation Laboratory (LRL).

#### 1.3 FIELD INVESTIGATIONS

Initial drilling at the site included a 36-inch-diameter<sup>1</sup> emplacement hole (U20-k) and two 9-7/8-inch-diameter instrumentation

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<sup>1</sup> A table of factors for converting British units of measurement to metric units is presented on page 11.

holes (U20k-1 and U20k-2) that were drilled by the Atomic Energy Commission (AEC) (see Table 1.1). None of these borings were logged with respect to lithology and fracturing.

Five borings were drilled at the site by the WES--a 5-1/2-inch-diameter hole (UE20k-1) and four NX-size holes (UE20k-2, -3, -4, and -5) (Table 1.1). The 5-1/2-inch-diameter hole was cored continuously to a depth of 351.0 feet. The NX holes were also cored continuously but varied in depth from 199.2 to 270.5 feet (Table 1.1). Lithologic logs of the NX and the 5-1/2-inch-diameter holes, all vertical borings, are shown in Appendix A of this report. A borehole camera survey was made of each of the borings numbered UE20k-1 through -4. Stranded drilling rods prevented the photographing of boring UE20k-5. The camera survey provided supplementary lithologic information that was especially useful in interpreting intervals of low core recovery.

Four selected core samples were taken from UE20k-1 for petrographic examination and X-ray diffraction analysis in the WES Concrete Division laboratory. The results of these examinations are presented in Appendix B.

Twelve representative core samples also were taken from boring UE20k-2 for testing in the WES Concrete Division laboratory to obtain data on the physical properties of the trachyte (e.g. static unconfined compressive strength and bulk dry and saturated surface-dry specific gravities). These data are evaluated in Chapter 3.

Neutron density logs and caliper logs were obtained from the 5-1/2-inch boring (UE20k-1) and from the two 9-7/8-inch instrumentation borings (U20k-1 and -2) by the Welex Company at the direction of LRL. These data are presented and evaluated in Chapter 4.

#### 1.4 PREVIOUS INVESTIGATIONS

The U. S. Geological Survey (USGS) has been conducting extensive geologic mapping and drilling programs on Pahute Mesa for the past several years. A summary of the USGS subsurface studies on Pahute Mesa is presented in Reference 1. The results of geologic mapping of the Trail Ridge quadrangle, which encompasses the Palanquin site, are to be published by USGS in the near future (Reference 2).

TABLE 1.1 SUMMARY OF SUBSURFACE INVESTIGATIONS OF THE PALANQUIN SITE

Boring	Coordinates <sup>a</sup>	Elevation	Total Depth	Angle of Boring	Type of Boring	Core Recovery	Borehole Camera Log Interval	Pressure Test Interval	Caliper Log Interval	Nuclear Density Log Interval
		feet, msl	feet			pct	feet	feet	feet	feet
UE20k-1	N921,171.17 E541,634.20	6193.1	351.0	Vertical	5-1/2 in.	73.2	3.0 to 350.0	None	0.0 to 350.0	0.0 to 349.0
UE20k-2	N921,035.87 E541,876.51	6184.1	270.1	Vertical	NX	74.8	3.0 to 268.0	None	None	None
UE20k-3	N920,988.92 E541,499.98	6180.8	270.5	Vertical	NX	40.9	5.0 to 269.0	10.0 to 213.3	None	None
UE20k-4	N921,272.03 E541,635.68	6190.5	199.2	Vertical	NX	16.2	36.0 to 180.0	None	None	None
UE20k-5	N921,215.44 E541,555.45	6193.4	217.7	Vertical	NX	27.2	None	None	None	None
U20k	N921,071.98 E541,635.51	6193.8		Vertical	36 in.	--	None	None	None	None
U20k-1	N920,981.08 E541,677.61	6194.0	350.0	Vertical	9-7/8 in.	--	None	None	0.0 to 347.0	0.0 to 347.0
U20k-2	N920,619.01 E541,846.73	6165.3	490.0	Vertical	9-7/8 in.	--	None	None	0.0 to 489.0	0.0 to 489.0

<sup>a</sup> Nevada state coordinate system.



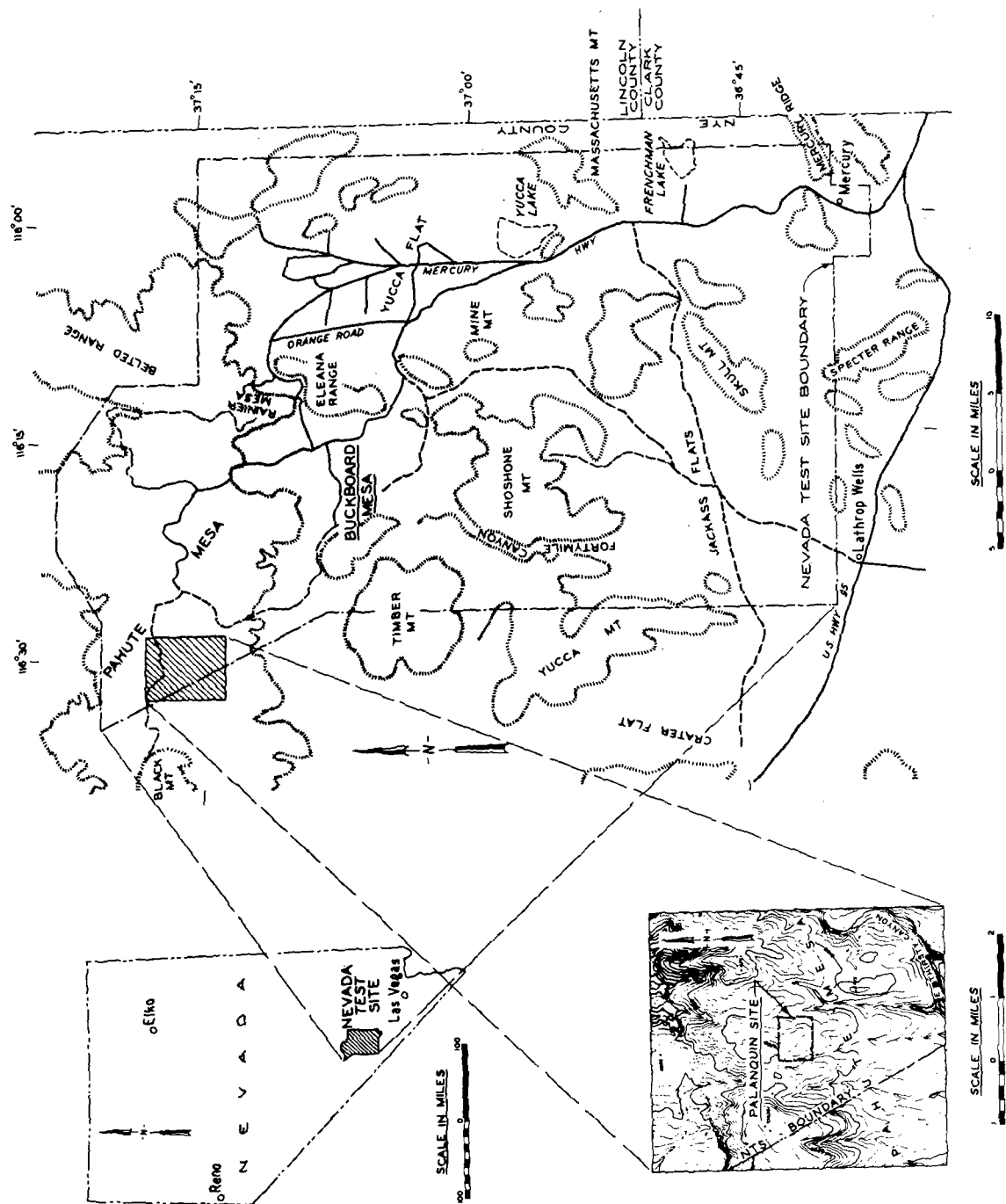


Fig. 1.1 General location map.

## CHAPTER 2

### GENERAL GEOLOGY

#### 2.1 LOCATION

The Palanquin site is located on Pahute Mesa within Area 20 of the NTS. Surface ground zero is located approximately 53 air miles north-northwest of Mercury, Nevada, and 7 miles due east of Black Mountain (see Figure 1.1). The Nevada state coordinates for surface ground zero are N921,071.98 and E541,635.51.

#### 2.2 PHYSIOGRAPHY

Pahute Mesa is a major, east-west trending, maturely dissected mesa of Tertiary volcanics that generally exceeds 6,000 feet in elevation and stands from 1,000 to 2,000 feet above the surrounding valleys. The Palanquin site (Figure 2.1) has an average elevation of approximately 6,190 feet and is located on a ridge, approximately 3,000 feet long by 1,500 feet wide, that slopes gently southward away from the axis of Pahute Mesa. Gently rolling hills and valleys are characteristic topography within a 2-mile radius of the site.

The USGS investigations indicate that the groundwater table in this vicinity is approximately 1,500 feet below the mesa surface. No perched water tables were encountered during the on-site drilling program.

## 2.3 REGIONAL GEOLOGY

According to References 1 and 2, the area in the immediate vicinity of the Palanquin site is underlain by Pliocene volcanic rocks that are masked by a thin residual soil and locally by Quaternary alluvium and colluvium deposits (see Figure 2.2). The igneous rocks cropping out in this area are included in either the Thirsty Canyon Tuff or the older Ribbon Cliff Rhyolite. Deep borings (Reference 1) indicate that the Ribbon Cliff Rhyolite is underlain by the Timber Mountain Tuff. These volcanic formations are described in the following discussion of the regional stratigraphy and are listed in order of decreasing age.

2.3.1 Timber Mountain Tuff. The Timber Mountain Tuff consists predominantly of partially to densely welded, gray, maroon, and black, devitrified and vitric, rhyolitic and quartz latitic tuff. Although the formation does not crop out in the vicinity of the site, it has been identified in several deep borings (Reference 1). In exploratory boring UE20j (Reference 1) (see Figures 2.2 and 2.3), the formation is 832 feet thick and consists mainly of welded tuff with minor amounts of vitric bedded tuff.

2.3.2 Ribbon Cliff Rhyolite. The Ribbon Cliff Rhyolite overlies the Timber Mountain Tuff in the area immediately east of Black Mountain. The Ribbon Cliff is a volcanic pile or mound built up by the superimposition of several successive rhyolitic and trachytic

flows. Generally restricted within a 6-mile radius of the Palanquin site, the Ribbon Cliff reaches a maximum observed thickness of 575 feet in boring U20k and thins rapidly in all directions (see Figures 2.2 and 2.3). In boring UE20j (Reference 1), situated approximately 1.4 miles north-northwest of boring U20k, the Ribbon Cliff is 268 feet thick. The Ribbon Cliff is absent in the following borings: boring FM#2 (Reference 1), 5.1 miles north-northwest of U20k; boring U20f, 2 miles east-southeast of U20k; and boring U20e, 4.4 miles northeast of U20k. The formation thins westward.

Only the uppermost flow of the Ribbon Cliff Rhyolite crops out east of Ribbon Cliff (Figure 2.2); and because it underlies the Palanquin site, it is treated with more detail than the other flows. This flow is a porphyritic trachyte that consists of numerous white phenocrysts of alkali feldspar set in a gray-brown or red-brown aphanitic or very fine-grained matrix. Moderately to steeply dipping red-brown flow layers are present locally. While this flow constitutes only a small portion of the formation in UE20j, it is at least 150 feet thick along Ribbon Cliff and at least 351 feet thick at the Palanquin site.

2.3.3 Thirsty Canyon Tuff. The Thirsty Canyon Tuff consists of a complex succession of rhyolitic welded and nonwelded tuffs that have been subdivided into five formal members and an upper informal member (Reference 3). Within the area of study, the Thirsty Canyon

Tuff normally overlies the Ribbon Cliff Rhyolite. However, where the Ribbon Cliff is absent, the Thirsty Canyon rests directly upon the Timber Mountain Tuff. Because of the marked topographic irregularity of the surface upon which it was deposited, Thirsty Canyon Tuff may show pronounced lateral variation, in thickness of individual members as well as in such things as the degree of welding or percent of phenocrysts, pumice, or lithic fragments (Reference 3). The thicknesses of the lower members are particularly variable, reaching a maximum where deposited in depressions and thinning or even pinching out against topographic highs on the depositional surface. Only the two lower members of this formation occur within the area of study: the Spearhead Member and the overlying Trail Ridge Member.

2.3.3.1 Spearhead Member. This basal member of the Thirsty Canyon Tuff is informally subdivided by the USGS into an upper and lower part to distinguish between an upper and lower cooling unit. Each part consists of maroon, gray, and brown, densely to partially welded rhyolitic tuffs with a thin basal, pumice-rich, ash-fall tuff. The upper part is distinguished by numerous red to brown lenses of scoriaceous to devitrified glass that are commonly as much as 1 foot thick and several feet in length. The upper and lower parts are highly variable in thickness, each ranging from 0 to 300 feet (Reference 3). In boring UE20j the upper part is 104 feet thick while the lower part is absent (Reference 1). The Spearhead Member,

particularly the lower part, has a very limited areal distribution within the study area (see Figure 2.2). Throughout most of the area, the lower part is absent, with the upper part resting upon the Ribbon Cliff Rhyolite. Commonly the entire member is absent and the younger Trail Ridge Member rests on the Ribbon Cliff. These anomalies are caused by the onlapping of progressively younger beds against topographic highs on the surface of deposition.

2.3.3.2 Trail Ridge Member. The Trail Ridge Member overlies the Spearhead Member and forms the caprock for a large part of Pahute Mesa. The member consists of a maroon, brown, or gray, partially to densely welded rhyolitic tuff, with common phenocrysts of sanidine. A thin basal, pumice-rich, ash-fall tuff is generally present. The member locally reaches almost 200 feet in thickness, but generally is much thinner. In boring UE20j (Reference 1), the member consists of 140 feet of welded tuff underlain by 38 feet of vitric bedded tuff. Although the Trail Ridge normally rests on the Spearhead Member, it commonly rests directly on the Ribbon Cliff Rhyolite because of its onlap relationship.

## 2.4 SITE GEOLOGY

The Palanquin site is underlain by the Ribbon Cliff Rhyolite upon which has formed a thin cover of residual soil.

2.4.1 Soil. At the site, a thin residual soil consisted of a

tan sandy silt containing sand- to boulder-size fragments of porphyritic trachyte. Soil thicknesses ranged from a minimum of 4 feet in UE20k-2 to a maximum of 13 feet in UE20k-4, with an average thickness of 8.7 feet.

2.4.2 Ribbon Cliff Rhyolite. Beneath the soil zone lies the upper flow of the Ribbon Cliff Rhyolite, at least 351 feet thick at the Palanquin site. Petrographic examination and X-ray diffraction tests on four selected core samples from boring UE20k-1 indicate this upper flow to be a trachyte. The results of these examinations are presented in Appendix B.

Visual core logging (see Appendix A) indicates this upper flow to be fairly uniform in lithology. It characteristically consists of a porphyritic trachyte, generally containing greater than 20 percent of white, usually equant, subhedral phenocrysts (averaging 1/4 inch in size) of alkali feldspar, set in a hard, dense, gray-brown or red-brown, aphanitic to very fine-grained matrix. Sand- to gravel-size subrounded xenoliths of tuffaceous material are present locally, as are moderately to steeply dipping red-brown flow layers.

The rock commonly may show various degrees of alteration and decomposition, particularly within very highly fractured zones produced by local faulting. The alteration commonly results in an increase in porosity of the rock matrix and in the decomposition of feldspars to clay minerals. Extreme alteration produces a rock that

is easily crumbled by hand. Zones of this highly fractured and altered material are indicated in the accompanying logs (Appendix A) and are responsible for large intervals of little or no core recovery. This alteration probably resulted from the circulation of warm aqueous solutions along fault planes and through adjacent fractured zones. These aqueous solutions are believed responsible for the precipitation of abundant hematite along fracture surfaces (see Appendixes A and B).

## 2.5 STRUCTURE

2.5.1 Faults. Several north-south trending high-angle normal faults occur within the area (Figure 2.2). A north-south trending syncline axis occurs between surface ground zero and Ribbon Cliff, probably representing a downwarping of the central portion of an uplifted fault block.

Subsurface investigations at the Palanquin site indicated the presence of a high-angle normal fault that was not delineated by surface mapping. This fault was inferred from the extensive zones of little or no core recovery in the upper portions of borings UE20k-1, -3, and -4, and in the lower portion of boring UE20k-5 (see Figures 2.4, 2.5, and 2.6). In boring UE20k-3, an average of 4.4 percent of core was recovered to a depth of 139.0 feet. A zone of poor to fair recovery, averaging 43.6 percent, occurred from 139.0 to 193.4 feet, followed by a zone of high core recovery, averaging 95.2 percent,



from 193.4 feet to a total depth of 270.5 feet. A similar situation was encountered in boring UE20k-4, where an average of 8.4 percent core was recovered to a depth of 169.2 feet. A zone of poor to fair core recovery, averaging 60.0 percent, occurred from 169.2 feet to a total depth of 199.2 feet. In UE20k-1 an average of 32.8 percent core was recovered to a depth of 79.4 feet, 67.4 percent core recovery was obtained in the interval from 79.4 to 146.4 feet, and 90.7 percent from 146.1 feet to a total depth of 351.0 feet. This 79.4-foot upper zone of poor core recovery is correlated with the thick upper zones of very poor core recovery in NX borings UE20k-3 and -4 (139.0 and 169.2 feet, respectively). The improved percent recovery in boring UE20k-1 is attributed to the use of a larger core barrel (5-1/2-inch). No zone of very poor core recovery was encountered in NX boring UE20k-2. The upper 53.9-foot-thick poor-fair core recovery zone in UE20k-2 (averaging 41.2 percent) was attributed to weathering.

The orientation of this fault was estimated by trigonometric means, assuming that the fault plane was essentially parallel to the effective base of the adjacent zone of intense fracturing. The effective base of this zone of fracturing was taken as the first significant increase in percent core recovery and occurs at a depth of 79.4 feet in boring UE20k-1, at 139.0 feet in boring UE20k-3, and at 169.2 feet in boring UE20k-4. Since the elevation of three points lying on the plane was known, the orientation of the

plane could be calculated. Apparent dips were calculated between borings UE20k-1 and -3, and between borings UE20k-1 and -4. These two apparent dips were plotted on a stereonet, and the true dip of the plane was determined. As a check, the true dip was also determined by graphic means through the solution of a standard three-point problem (Reference 4). Both methods yielded comparable results. The fault plane was found to be striking N27°E and dipping 64 degrees to the northwest. This fault was tentatively believed to be an extension of a fault mapped by the USGS south of the site (see Figure 2.2), and it intersected the surface at a point 10 feet west of the emplacement hole U20k.

The thickness of this zone of intense fracturing was determined from the information obtained from boring UE20k-5. This boring was positioned 90 feet away from boring UE20k-1, in the down-dip direction, for the purpose of determining the top of the fracture zone (the base of the hanging wall). Boring UE20k-5 encountered an upper zone of poor to fair core recovery, 50.2 feet thick, that averaged 22.1 percent in recovery (probably due to weathering); a middle zone of good recovery, averaging 84.3 percent in recovery, from 50.2 to 98.0 feet in depth; and a lower zone of very poor recovery, averaging 6.5 percent in recovery, from 98.0 to 217.7 feet in depth (Figure 2.6). Unfortunately, the drilling rods were lost after reaching a depth of 217.7 feet, and drilling was suspended before reaching

the base of the fracture zone (estimated depth of intersection is 262.2 feet). The thickness of the fracture zone (measured normal to the plane of faulting) was calculated to be 73 feet (assuming the zone dips 64 degrees and intersects boring UE20k-5 from a depth of 98.0 to 262.2 feet).

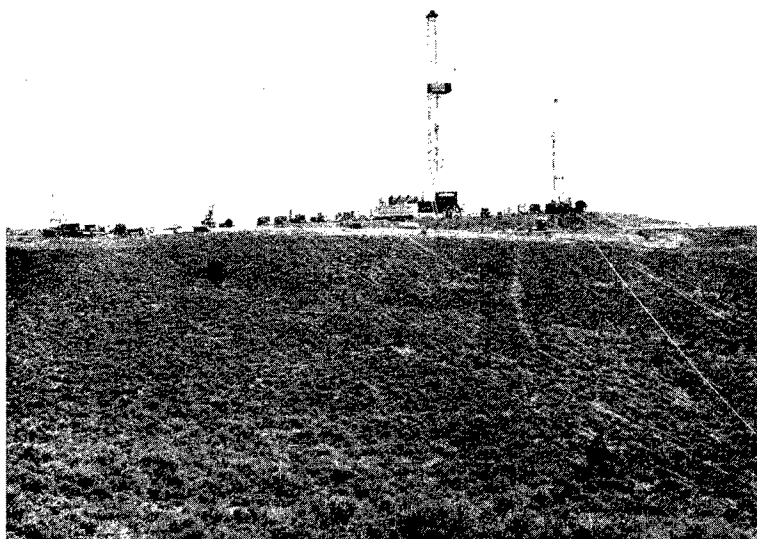
2.5.2 Joints. Several surface exposures of the Ribbon Cliff Rhyolite, cropping out in the valley north of the site, were examined briefly for fracture patterns. These outcrops have the following Nevada state coordinates:

N924,350 E547,550	N922,775 E547,000
N922,800 E540,700	N923,040 E539,650
N923,060 E539,300	N925,700 E545,060
N924,500 E544,250	N924,850 E543,400
N924,650 E542,350	

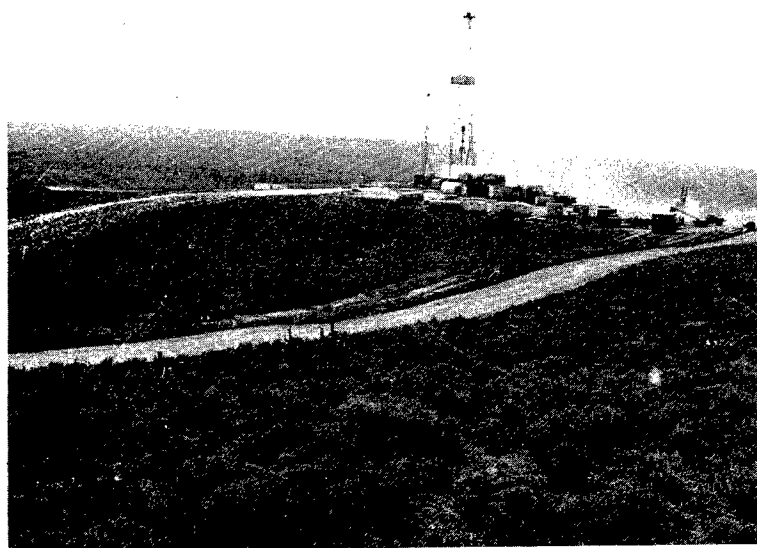
The surface exposures are well jointed, with from two to four joint sets present at a given outcrop. The joints are generally high-angle fractures, dipping greater than 60 degrees, and can be grouped into two major and two minor strike sets. The strikes of one major set vary from N45°W to N78°W, and average N65°W. The other major set has strikes that vary from N30°E to N75°E, and average N55°E. The two minor sets have average strike values of N16°W and N15°E. Low-angle joints that parallel flow layers are important locally.

Spacing between joints of a particular set varies from one locality to another, depending on whether or not it is locally a dominant joint set. Dominant joint sets have a spacing that ranges

from 2 feet to less than 1 inch. Other joint sets have a spacing that varies from 3 to 10 feet. A cursory examination of borehole photography indicates that the frequency of joints decreases with depth, except near fault zones.



a. As viewed from southeast.



b. As viewed from northeast.

Figure 2.1 General views of Palanquin site.

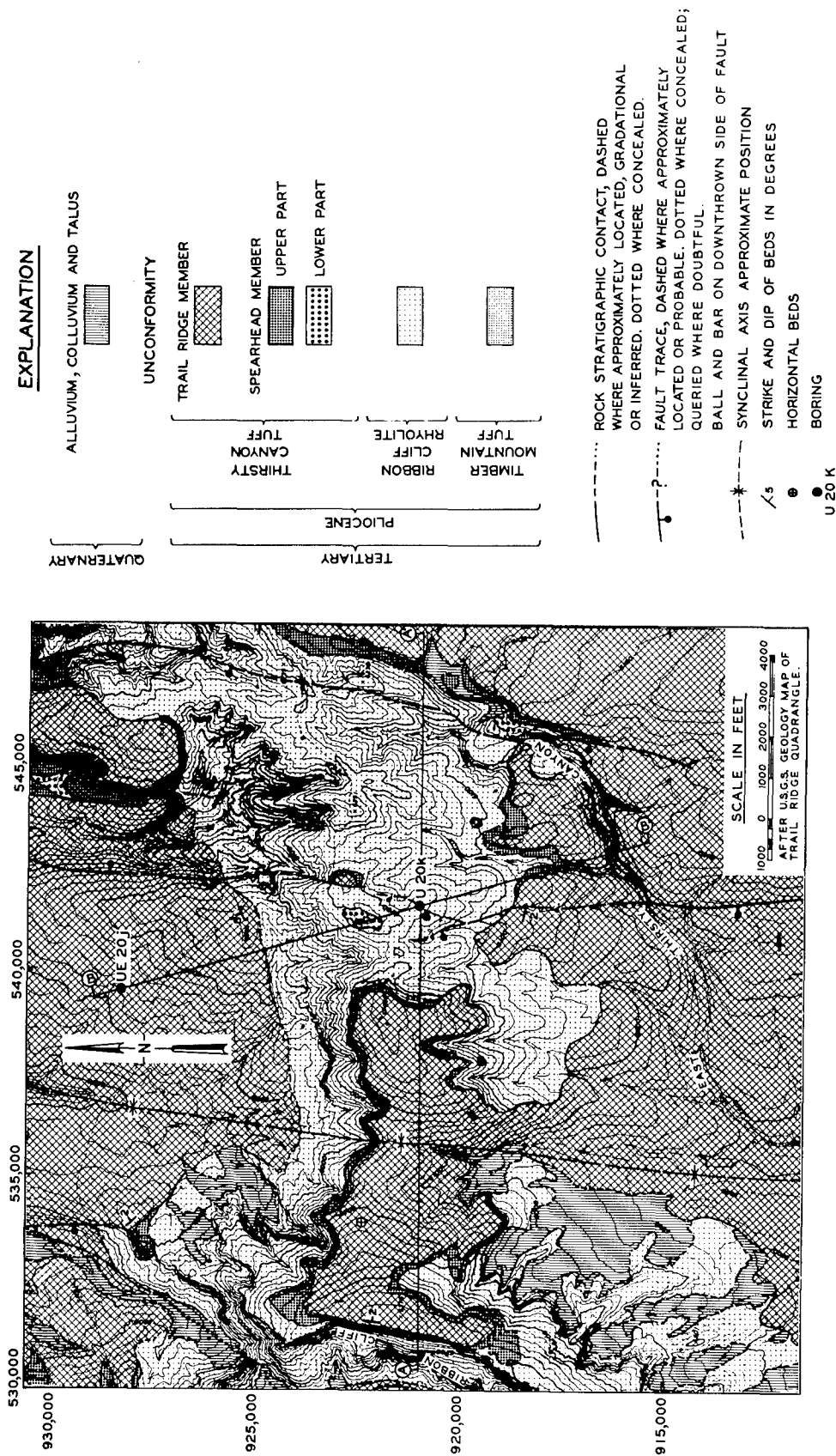


Figure 2.2 Geologic map of Palanquin site and surrounding area. Generalized cross sections through surface ground zero, A-A' and B-B', are positioned on the map and are illustrated in Figure 2.3.

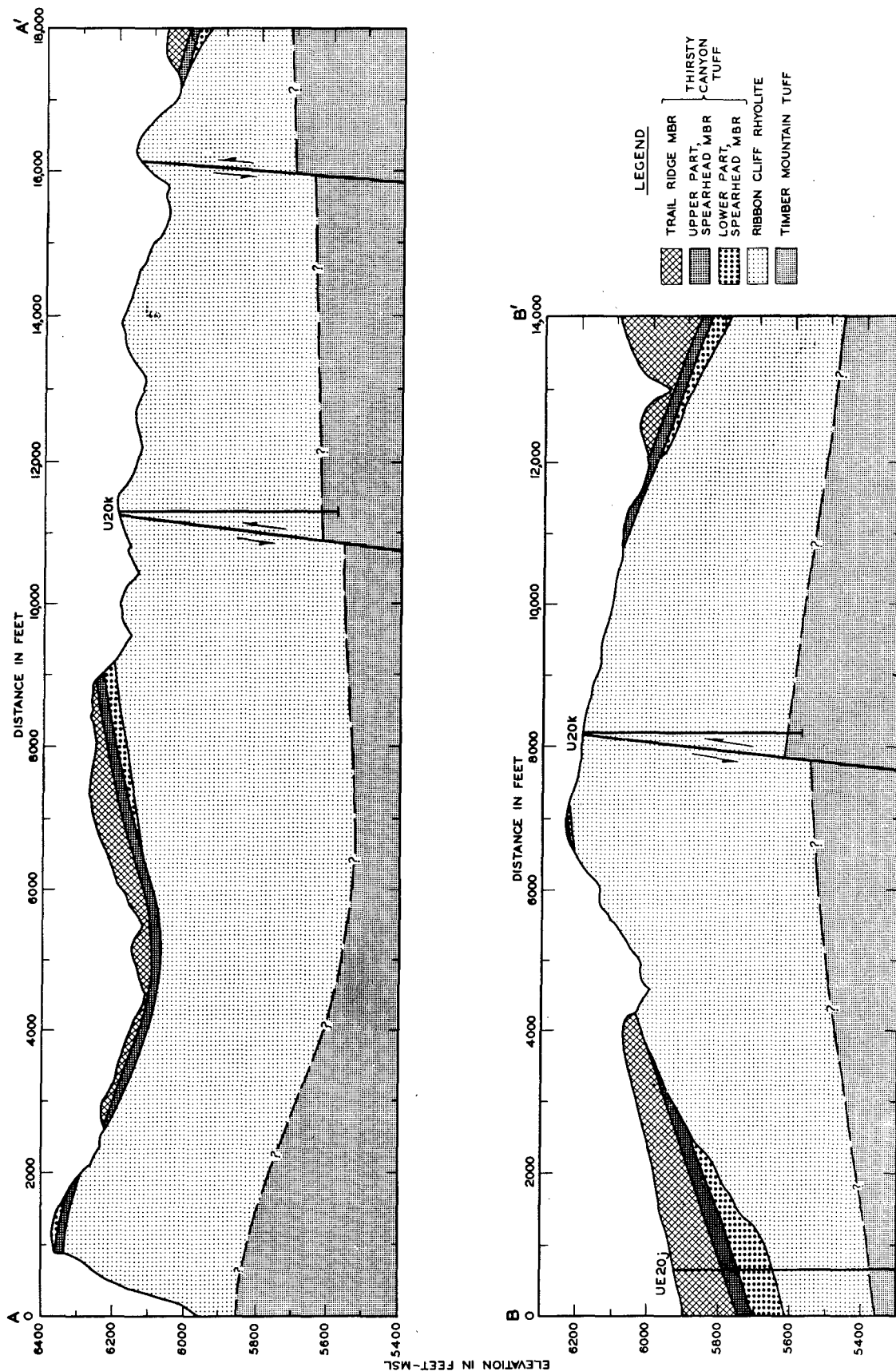


Figure 2.3 Generalized cross sections A-A' and B-B' drawn through Palanquin site and surrounding area. Location of sections shown in Figure 2.2.

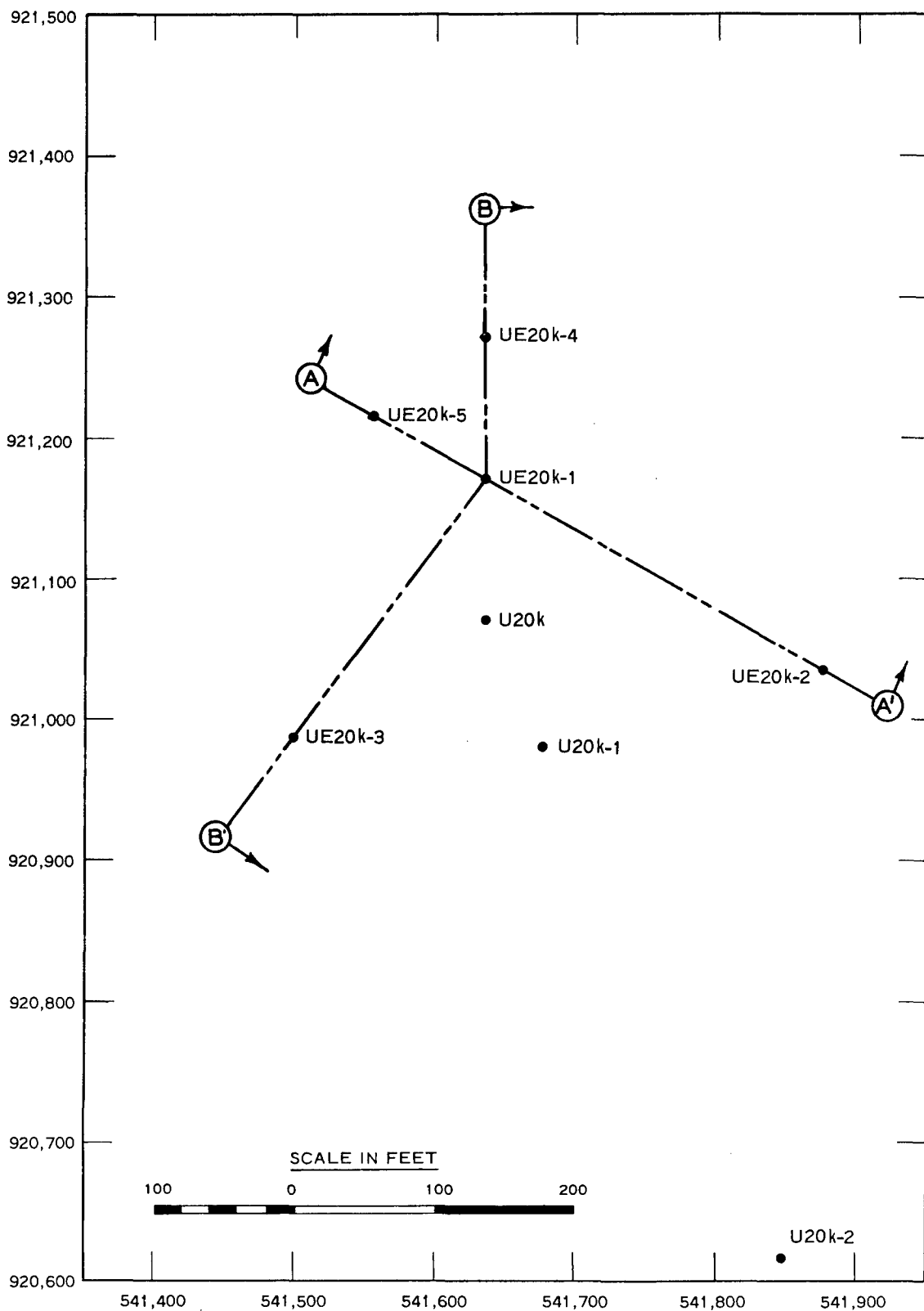


Figure 2.4 Plan of borings drilled at Palanquin site and location of sections A-A' and B-B' shown in Figure 2.5 (showing Nevada state coordinates).



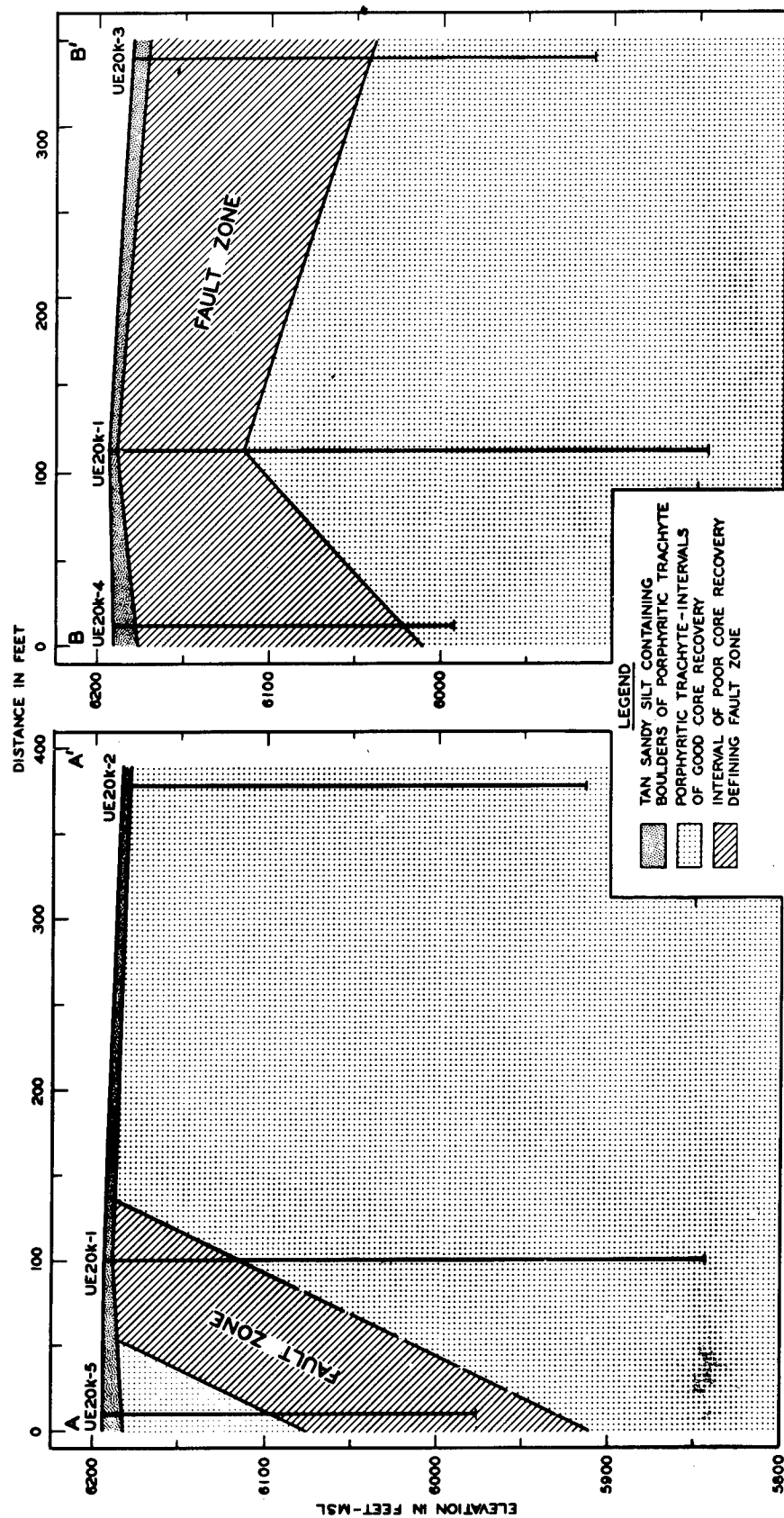


Figure 2.5 Geologic cross sections A-A' and B-B' drawn through Palanquin site. Location of sections shown in figure 2.4.

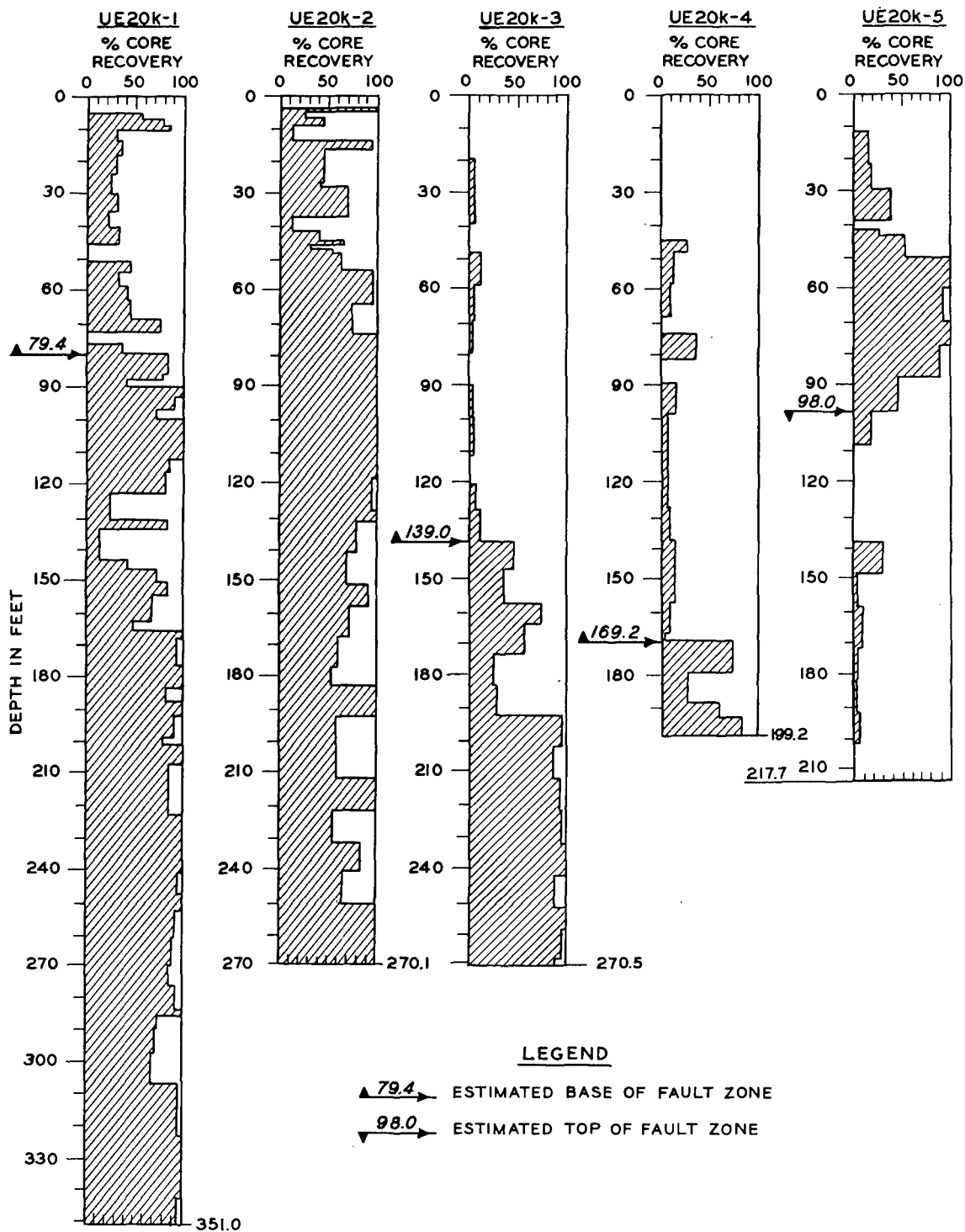


Figure 2.6 Variation of percent core recovery with depth in five borings drilled at Palanquin site.

## CHAPTER 3

### PHYSICAL PROPERTIES OF PORPHYRITIC TRACHYTE

#### 3.1 SAMPLE DESCRIPTION

Twelve core samples from drill hole UE20k-2, considered representative of the Palanquin site, were subjected to detailed examination and physical testing by the Concrete Division, WES. Sketches and descriptions of these samples are shown in Appendix B.

All samples contained feldspar phenocrysts and small reddish hematite crystals. The longest dimension of the feldspar phenocrysts observed in the 12 samples varied between  $1/2$  and  $3/4$  inch and appeared to be greatest in the two specimens between depths of 64 and 109 feet.

The samples also contained small, narrow, unoriented cracks. The minimum average length of the cracks observed in the surface of the samples was approximately  $1/4$  inch; the maximum average length was  $3/4$  inch.

#### 3.2 PHYSICAL TESTS

3.2.1 Specific Gravity. The bulk specific gravity ( $G_m$ ) under saturated surface-dry (SSD) conditions and the bulk dry specific gravity ( $G_o$ ) of the 12 samples from boring UE20k-2 were determined using test method CRD-C 23-65, Reference 5. The bulk dry specific gravity was also determined for the four samples from borehole UE20k-1

on which petrographic analyses were made. The equations employed are given in Appendix B.

The results of the bulk dry specific gravity determinations and corresponding dry bulk density values for the four specimens from boring UE20k-1 are shown in Table 3.1. Density values were obtained by multiplying the bulk specific gravity values by the unit weight of water.

The results of the specific gravity determinations on the 12 specimens from borehole UE20k-2 and the corresponding SSD and dry bulk density values are shown in Table 3.2. The SSD bulk specific gravity and corresponding density values for the samples may not be true values inasmuch as the saturated surface-dry weight in air would be slightly less than the weight of the ideally saturated sample because water is not retained in the larger openings on the surface. The SSD bulk specific gravity values ranged from a maximum of 2.58 to a minimum of 2.49 and averaged 2.54. The standard deviation was 0.03 (Reference 6). The bulk dry specific gravity values ranged from a maximum of 2.53 to a minimum of 2.43 and averaged 2.49. Again the standard deviation was 0.03. The average in situ bulk specific gravity value is considered to be closer to the average dry bulk specific gravity value, 2.49 (155 pcf).

3.2.2 Static Strength. The static compressive strength of the 12 rock samples was determined by unconfined compression tests.

The length-diameter ratio was approximately 2.0 for all specimens. The ends of the rock cores were prepared for testing by surface grinding. Experience has shown that when brittle rock is tested for static strength with ends ground, the strength values are slightly higher than when ends are capped. A uniform loading rate of 50 psi/sec was applied to all specimens. Strains were measured by two diametrically opposed SR-4 strain gages bonded to the specimen. Values of unconfined compressive strength for rock samples from boring UE20k-2 are shown in Table 3.2.

Static unconfined compressive strength values ranged from a maximum of 16,250 psi to a minimum of 9,860 psi and averaged 13,370 psi; the standard deviation was 2,200 psi.

Plots of compressive strength and bulk dry specific gravity with depth are shown in Figure 3.1. The compressive strength tends to increase with increasing specific gravity. The relatively lower unconfined compressive strength of the sample at a depth of 19 feet is attributed to its proximity to the surface and a possible loss of strength due to weathering.

3.2.3 Modulus of Elasticity. The stress-strain curves for the compressive tests are presented in Appendix B. Static modulus of elasticity values were derived from the stress-strain curves and are shown in Table 3.2. The modulus of elasticity computed for all except one core sample was a tangent modulus taken at 7,040 psi on

each curve. This modulus was considered more appropriate for the stress-strain curves than others such as secant modulus. The modulus of elasticity computed for the exception was an initial tangent modulus of the stress-strain curve. The maximum modulus of elasticity value was  $4.89 \times 10^6$  psi; the minimum value was  $2.70 \times 10^6$  psi; the average was  $3.80 \times 10^6$  psi. The standard deviation was  $0.76 \times 10^6$  psi.

3.2.4 Poisson's Ratio. Values of Poisson's ratio, determined from laboratory tests, are shown in Table 3.2. Values ranged from 0.18 to 0.38, and averaged 0.26. The standard deviation was 0.04.

TABLE 3.1 DRY BULK SPECIFIC GRAVITY AND BULK DENSITY OF SAMPLES FROM  
BORING UE20k-1

Sample Depth	Dry Bulk Specific Gravity	Dry Bulk Density
feet		pcf
105	2.48	155
140 <sup>a</sup>	2.15	134
214.5 to 215.5	2.54	158
306.8	2.42	151

<sup>a</sup> Weathered and altered.

TABLE 3.2 RESULTS OF PHYSICAL TESTS ON SAMPLES FROM BORING UE20k-2

Depth	Bulk Specific Gravity		Bulk Density		Compressive Strength	Modulus of Elasticity <sup>a</sup>	Poisson's Ratio
	Dry		SSD				
	Dry	SSD	pcf	pcf			
feet							
18.3 to 19.3	2.48	2.54	155	159	9,860	3.75	--
43.5 to 44.1	2.44	2.50	152	156	10,930	4.36 <sup>b</sup>	0.20
73.9 to 74.8	2.45	2.51	153	157	13,420	4.66	0.38
99.5 to 100.8	2.49	2.54	155	159	13,240	4.89	0.20
117.2 to 118.7	2.51	2.56	157	160	15,180	4.40	0.18
152.4 to 153.3	2.52	2.58	157	161	16,030	4.39	0.25
171.3 to 172.4	2.51	2.56	157	160	14,680	3.22	0.25
185.2 to 186.1	2.51	2.55	157	159	13,030	3.69	0.26
203.0 to 203.6	2.43	2.49	152	155	10,850	2.70	0.30
221.6 to 222.2	--	2.54	--	159	--	--	--
243.0 to 243.7	2.53	2.58	158	161	16,250	3.88	0.31
268.6 to 269.8	2.51	2.56	157	160	13,650	2.79	0.25
268.6 to 269.8	2.51	2.56	157	160	13,320	2.82	0.27

<sup>a</sup> Modulus of elasticity computed for all cores except one was a tangent modulus taken at 7,040 psi on each curve.

<sup>b</sup> Modulus of elasticity computed for this core was an initial tangent modulus taken from the origin of the curve.



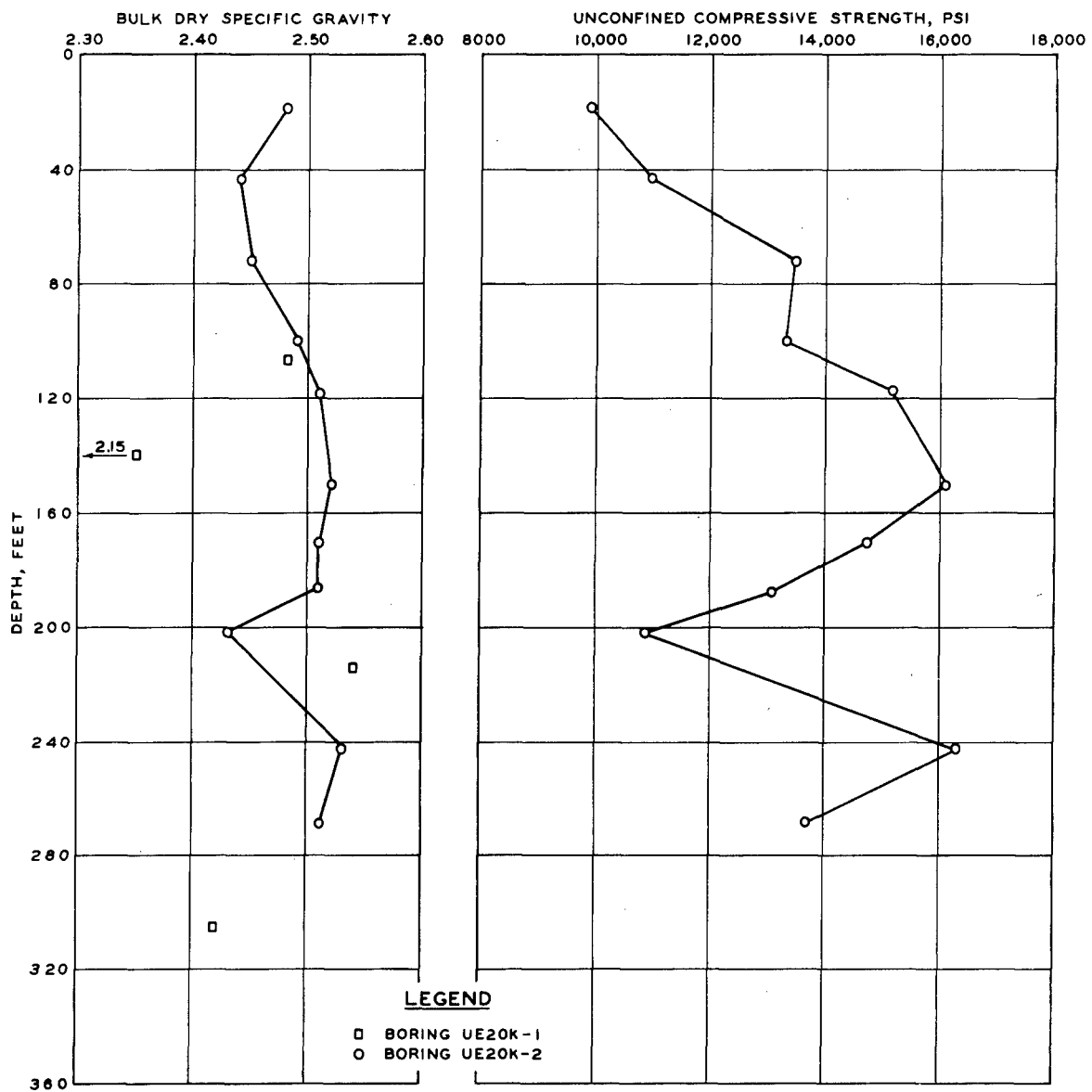


Figure 3.1 Bulk dry specific gravity and unconfined compressive strength versus depth.

## CHAPTER 4

### GEOPHYSICAL LOGGING AND PRESSURE TESTS

#### 4.1 GEOPHYSICAL LOGGING

The in situ density of the porphyritic trachyte at the Palanquin site was investigated by means of geophysical logs obtained by the Welex Company in AEC borings U20k-1 and -2 and WES boring UE20k-1. The geophysical logs, which consisted of a density log and a caliper log, were conducted in dry holes. These logs from boring UE20k-1 are shown in Figure 4.1. Those from borings U20k-1 and -2 are shown in Figure 4.2.

The in situ density values in boring UE20k-1 were compared with laboratory-determined dry density values on four core samples obtained from boring UE20k-1 at corresponding locations. This comparison is shown in Figure 4.1.

The in situ density values obtained from density logs of borings U20k-1 and -2 were compared with laboratory-determined dry density values on 12 core samples obtained from boring UE20k-2 (Figure 4.2), inasmuch as the latter borehole was located nearest these borings and borings U20k-1 and -2 were not cored.

4.1.1 Density Logging. The in situ density of the media encountered in each boring was determined directly from the Welex departure curves for air-filled holes attached to the density log of

borehole UE20k-1. Welex departure curves indicated that for a condition of porosity registering 1000 counts/sec in a 5-1/2-inch-diameter hole, the in situ density was approximately  $2.6 \text{ g/cm}^3$ . The lowest number of counts recorded in boring UE20k-1 was approximately 650. This value represents in situ material having the lowest porosity and the highest bulk density, approximately  $2.95 \text{ g/cm}^3$  or 184 pcf. The highest dry bulk density value determined in the laboratory on a sample from boring UE20k-1 was 158 pcf. Thus, the maximum in situ density value of 184 pcf, designated as representative of density at 650 counts by the Welex departure curves, was approximately 16 percent greater than the maximum density value obtained in the laboratory.

In previous site investigations, comparisons of laboratory-determined density values with in situ density values obtained by geophysical logging at corresponding locations showed that in situ values are commonly lower by several percent than laboratory values (Reference 7). According to the Welex Logging Company the great variations in borehole diameter disclosed by the caliper log made a quantitative analysis impossible. Consequently, the comparison of in situ density values obtained by geophysical logging with density values determined in the WES soils laboratory was limited to noting the trend of density with depth rather than making a quantitative comparison.

In general, density logs from borings UE20k-1, U20k-1, and U20k-2

exhibited a most erratic behavior in the upper 155 feet. This behavior is attributed to the wide variation in borehole diameter resulting from failures in the borehole walls that appeared to be due primarily to the presence of weaker materials.

In situ density below a depth of 150 feet in portions of the boreholes most closely approximating the bit size appears to remain constant with depth. A corresponding trend with depth was indicated by the laboratory density values.

4.1.2 Caliper Logging. The variations of borehole diameter with depth in borings UE20k-1, U20k-1, and U20k-2 are shown in Figures 4.1 and 4.2. The frequency of variations in borehole diameter and the magnitude of these variations appeared to be greatest in the upper 155 feet of these borings. Below this depth the variations in borehole diameter were separated from each other by a segment of borehole that more closely approximated the bit size. The larger borehole diameters are generally associated with the weaker and less dense materials.

#### 4.2 WATER PRESSURE TESTS

Water pressure tests were conducted during drilling operations in boring UE20k-3 at 10-foot increments to a depth of 213 feet. Each test interval was the bottom 10 feet of the borehole, which had been sealed off from the upper portion of the borehole by an expandable

rubber packer. The average flow rate was determined by measuring with a flow meter the quantity of water pumped into the hole for a measured period of time, generally three minutes. During this period, the water pressure in the pipe was maintained as nearly constant as possible. The horizontal permeability of various depth intervals was calculated from the water pressure test data using the following equation (Reference 8):

$$k = \frac{q}{2\pi Lp} \times \left( \log \frac{L}{r} + 1/2 \right)$$

where

$k$  = permeability, cm/sec

$q$  = steady flow rate, cm<sup>3</sup>/sec

$L$  = length of borehole interval tested, cm

$p$  = differential pressure inducing flow, g/cm<sup>2</sup>

$r$  = radius of borehole, cm

Results of the permeability calculations are shown in Figure 4.3.

The calculated values of coefficient of permeability were about  $35 \times 10^{-4}$  cm/sec near the surface, and they approached zero at about 110 feet below the surface. No data were obtained at depths between 110 and 139.5 feet, and no reliable data were obtained between depths of 139.5 and 203 feet because the capacity of the equipment was exceeded by requirements of high rates of flow. Between the

depths of 203 and 213 feet, permeability was  $27 \times 10^{-4}$  cm/sec.

Another means of expressing effective permeability is by use of a water loss coefficient. This method was suggested by de Mello and da Cruz (Reference 9). To express quantitatively the results of pressure tests, the water loss coefficient,  $P_i$ , was calculated using the following equation:

$$P_i = \frac{Q}{LH}$$

where

$Q$  = flow rate, gal/min

$L$  = length of borehole interval, feet

$H$  = pressure at mid-height of borehole interval, atmospheres

Because of high friction losses in the riser pipe, values of  $H$  between depths of 133.5 and 203 feet in borehole UE20k-3 indicated improbable conditions of a vacuum. Consequently,  $P_i$  values were meaningless between these depths and have, therefore, been omitted in the graph showing water loss coefficient versus depth (see Figure 4.3). Dimensionally, the water loss coefficient can be expressed approximately as coefficient of permeability in cm/sec by multiplying by 0.0020.

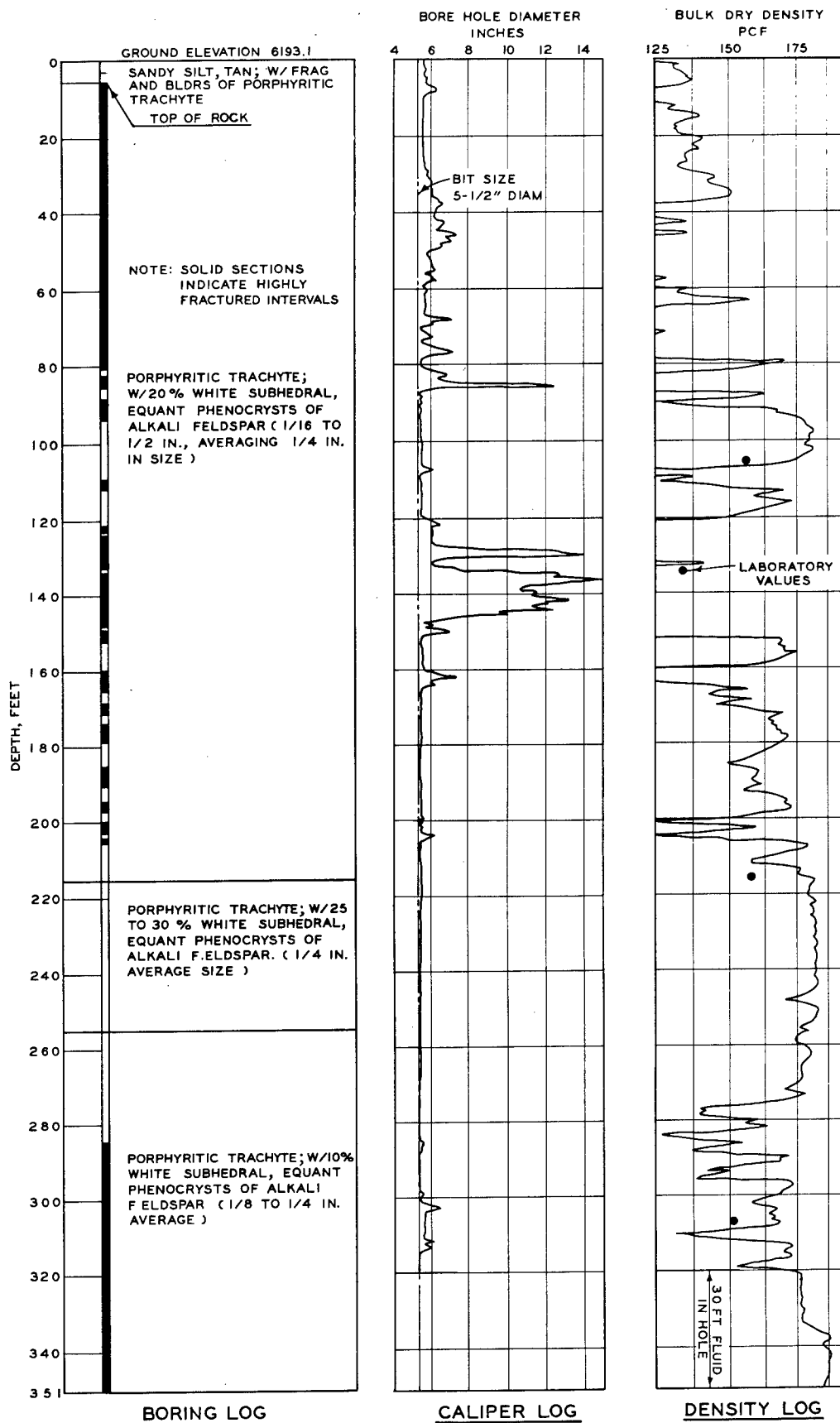


Figure 4.1 Boring log, caliper log, and density log for boring UE20k-1.

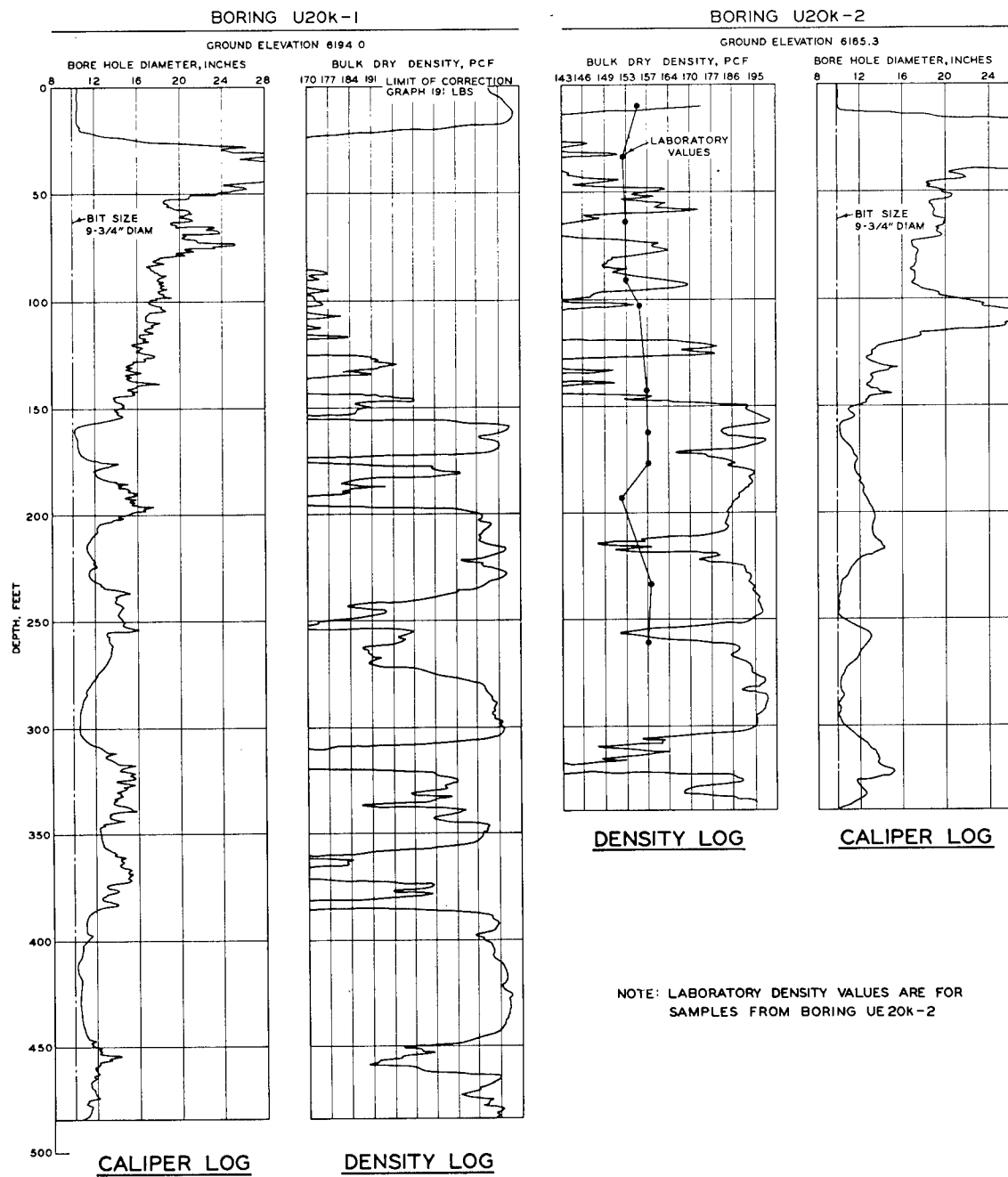


Figure 4.2 Caliper log and density log for borings U20k-1 and U20k-2.



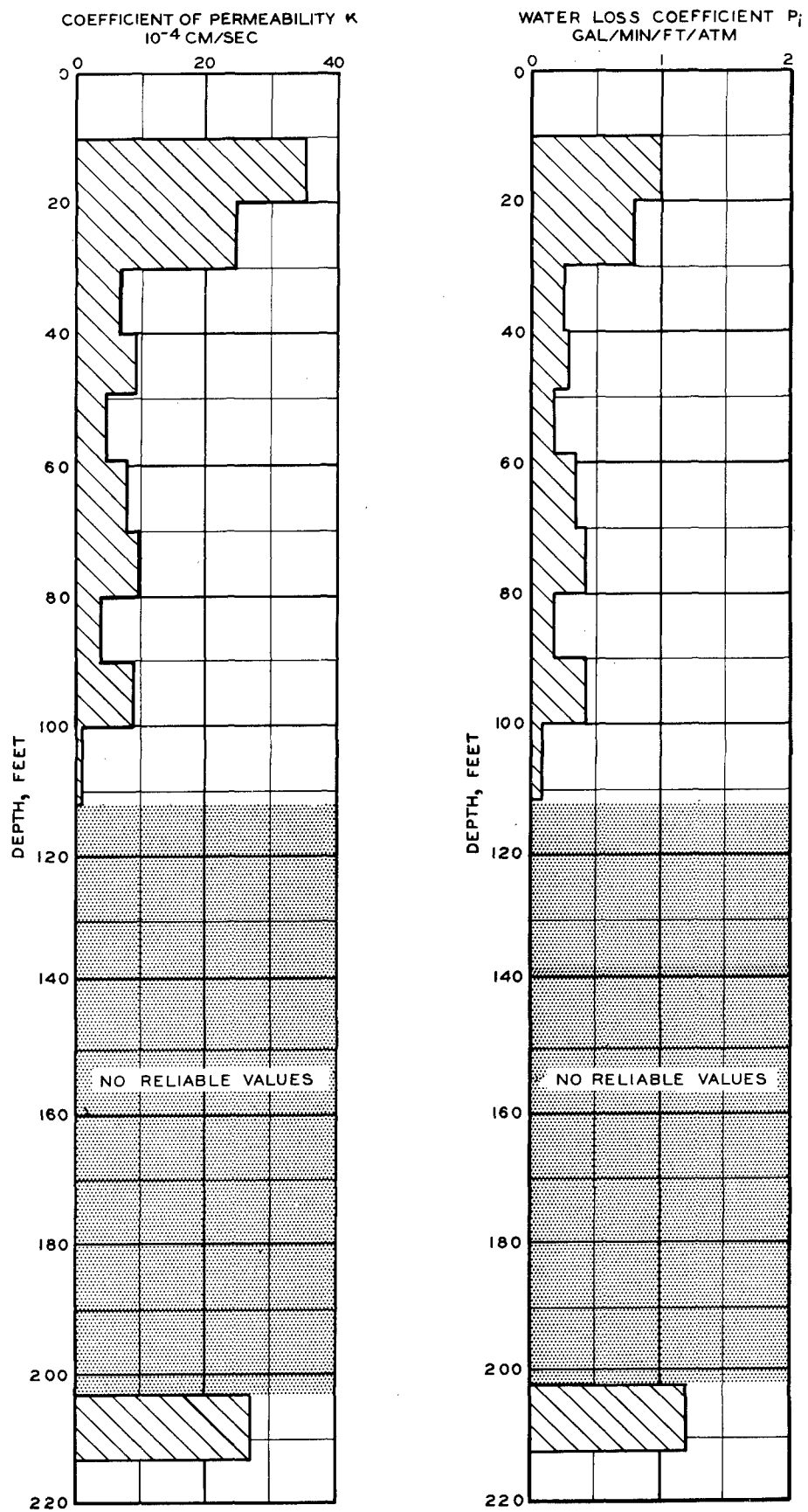


Figure 4.3 Water pressure tests, boring UE20k-3.

## CHAPTER 5

### SUMMARY

The site selected for the Palanquin event is located on a small, gently sloping nose on Pahute Mesa, within Area 20 of the NTS. A soil layer, 4 to 13 feet thick, overlies rock at the site. It is basically a residual soil consisting predominantly of sandy silt with sand- to boulder-size fragments of porphyritic trachyte. Beneath the soil zone lies the Ribbon Cliff Rhyolite, a succession of rhyolitic and trachytic lava flows that reaches a maximum thickness of 575 feet beneath surface ground zero. The upper flow of this succession is a porphyritic trachyte that is at least 351 feet thick. Although it is generally a hard competent rock, the porphyritic trachyte has been severely altered and decomposed within the numerous zones of intense fracturing that are related to local faulting. The Ribbon Cliff Rhyolite is underlain by the Timber Mountain Tuff, a thick succession of welded tuffs and vitric bedded tuffs.

Subsurface investigations at the site indicated the presence of a high-angle normal fault that strikes N27°E and dips 64 degrees to the northwest. This fault plane is enveloped by a 73-foot-thick tabular zone of intense fracturing with base intersecting the surface at a point 10 feet west of surface ground zero (U20k).

Data collected from outcrops north of the site indicate that the joints generally dip at high angles and form four sets, each with a characteristic average strike direction--two major sets striking N65°W and N55°E and two minor sets striking N16°W and N15°E. Joints of the dominant sets tend to be spaced at intervals less than 2 feet apart while minor joints may be spaced from 3 to 10 feet apart. The frequency of joints varies considerably with depth.

Physical tests indicated the average physical property values of the porphyritic trachyte to be: dry bulk specific gravity, 2.49; dry bulk density, 155 pcf; bulk SSD specific gravity, 2.54; SSD bulk density, 159 pcf; static unconfined compressive strength, 13,370 psi; modulus of elasticity,  $3.8 \times 10^6$  psi; and Poisson's ratio, 0.26. There appears to be a close relation between static unconfined compressive strength and density. The average in situ density is considered to be closer to the average dry bulk density.

Geophysical logging consisting of density and caliper logs disclosed that the in situ density values obtained were not quantitatively comparable to values determined in the laboratory, due to the erratic variations in borehole diameter indicated by the caliper logs. Although it was not possible to establish the trend of in situ density with depth above 150 feet due to the diameter variations, the trend of in situ density with depth below 150 feet appeared to approximate the trend indicated by physical tests,

i.e. no major variations of density with depth. The intervals of enlarged borehole diameters indicated by the caliper logs were generally associated with the weaker and less dense materials. Caliper logging conducted in borings in the southeast portion of the Palanquin site disclosed apparently weaker than average material at 150 feet and in several intervals below that depth.

Pressure tests indicated that permeability of the media at the Palanquin site was approximately  $35 \times 10^{-4}$  cm/sec near the surface and decreased with depth to practically zero at a depth of 110 feet. No pressure test data were obtained between depths of 110 and 139.5 feet. Pressure test data obtained between depths of 139.5 and 203 feet were unreliable due to excessive head losses in the riser pipe. Between depths of 203 and 213 feet, the permeability was  $27 \times 10^{-4}$  cm/sec. No pressure test data were obtained below a depth of 213 feet.

APPENDIX A  
LITHOLOGIC LOGS

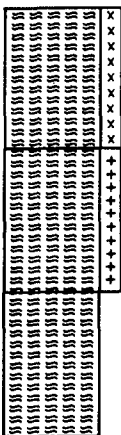
# LEGEND FOR PALANQUIN LITHOLOGIC LOGS



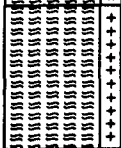
SANDY SILT, TAN; WITH FRAGMENTS AND  
BOULDERS OF PORPHYRITIC TRACHYTE



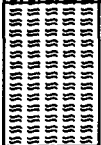
PORPHYRITIC TRACHYTE



PORPHYRITIC TRACHYTE; VERY HIGHLY  
FRACTURED



PORPHYRITIC TRACHYTE; HIGHLY  
FRACTURED



PORPHYRITIC TRACHYTE; SLIGHTLY TO  
MODERATELY FRACTURED

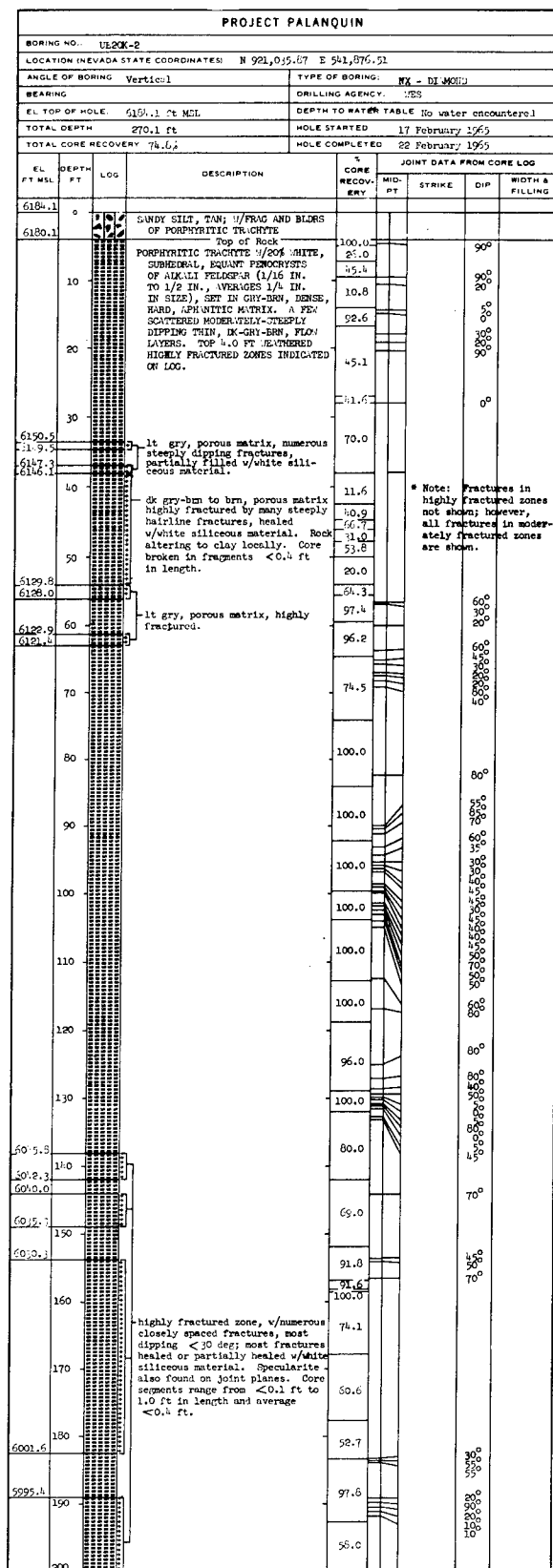
PROJECT PALANQUIN									
BORING NO. UE20K-1									
LOCATION: NEVADA STATE COORDINATES: N 921,171.17 E 541,654.20									
ANGLE OF BORING: Vertical		TYPE OF BORING: 4-1/2 by 5-1/2 in. Diamond							
BEARING		DRILLING AGENCY: VES							
EL TOP OF HOLE: (193.1) ft MSL		DEPTH TO WATER TABLE: No water encountered							
TOTAL DEPTH: 351.0 ft		HOLE STARTED: 1 February 1965							
TOTAL CORE RECOVERY: 73.24		HOLE COMPLETED: 16 February 1965							
EL. FT. MSL	DEPTH FT.	LOG	DESCRIPTION	% CORE RECOVERY	JOINT DATA FROM CORE LOG	STRIKE	DIP	WIDTH & FILLING	
5192.1	0		SANDY SILT, TAN; W/FRAG AND BLURS OF PORPHYRITIC TRACHYTE						
6192.0			Top of Rock	57.1					
	10		PORPHYRITIC TRACHYTE; w/30% WHITE, SUBHEDRAL, EQUITANT PHENOCRYSTS OF ALKALI FELDSPAR (1/16 TO 1/2 IN., AVERAGING 1/4 IN. IN SIZE), SET IN GRAY-BRN, DENSE, HARD VERY FINE-GRAINED MATRIX, CONTAINS 0 TO 10% SMALL VESICLES. FLOW STRUCTURES EMPHASIZED BY IRREGULAR RED-BRN SWIRLS AND STEEPLY DIPPING LAYERS. SMALL SUBROUNDED XENOLITHS ALSO PRESENT.	78.9 85.7 31.4					
	20			37.2					
	30			30.8					
	40			26.1					
	50			32.7					
	60		core badly decomposed, and porous to depth of 35.0 ft; very highly fractured.	21.8					
6174.4				34.0					
	50		Porphyritic trachyte w/red-brn matrix. Very highly fractured. Core broken into fragments 0.1 to 0.3 ft in length, striations on plane dipping 20 deg found at depth 58.8 ft.	0.0 0.0 45.7 31.7					
6126.3				41.9					
	70			45.9					
6111.7			common flow structures, very highly fractured, core broken into fragments <0.1 ft in length.	76.9 0.0 0.0 37.9					
	80			85.7					
	90			80.0 41.7 100.0					
	100			93.0					
	110			72.7					
	120			100.0					
	130			100.0					
	140			88.1					
	150			81.9					
	160			84.7					
	170			86.8					
	180		Very highly fractured to highly fractured zones, w/numerous hairline fractures, dipping 60 to 80 deg, partial filled w/gray-white clay. Core is broken into fragments <0.4 ft in length, badly decomposed and porous w/feldspar altering to clay. Specularite disseminated throughout zones. Striations on fracture planes.	11.4 44.4 75.0					
	190			85.7					
	200			69.5					
				50.0 100.0					
				95.5					
				100.0					
				84.4					
				100.0					
				94.1					

(Continued)

PROJECT PALANQUIN									
BORING NO. UE20K-1 (Continued)									
EL. FT. MSL	DEPTH FT.	LOG	DESCRIPTION	% CORE RECOVERY	JOINT DATA FROM CORE LOG	STRIKE	DIP	WIDTH & FILLING	
5993.1	200			80.0					
	210			100.0					
5979.1				87.0					
	220		PORPHYRITIC TRACHYTE, w/25 TO 30% WHITE, SUBHEDRAL, EQUITANT PHENOCRYSTS OF ALKALI FELDSPAR (1/4 IN. AVERAGE SIZE) SET IN GRAY-BRN, HARD, VERY FINE-GRAINED MATRIX. FLOW STRUCTURE COMMON AS LAYERS DIPPING UP TO 20 DEG	87.5					
	230			100.0					
	240			100.0					
	250			95.6					
5938.5				100.0					
	260		PORPHYRITIC TRACHYTE, w/10% WHITE, SUBHEDRAL, EQUITANT, PHENOCRYSTS OF ALKALI FELDSPAR (1/8 TO 1/4 IN. AVERAGE) SET IN, LT. GRAY, HARD, VERY FINE-GRAINED MATRIX MODERATELY-HIGHLY FRACTURED, w/ALL FRACTURES FILLED OR PARTIALLY FILLED w/WHITE SILICEOUS MATERIAL.	95.2					
	270			89.8					
	280			86.6					
	290			92.8					
	300			100.0					
	310			75.7					
	320		highly fractured, by numerous closely spaced fractures that dip from 0 to 30 deg, filled or partially filled w/white siliceous material. From 285.0 to 308.0 ft, core is broken into fragments generally <0.3 ft; from 308.0 to 351.0 ft core in fragments generally between 0.5 to 1.5 ft in length.	72.4					
	330			97.9					
	340			100.0					
5942.1	350			95.1					

BOTTOM DEPTH: 351.0 FT  
 BOTTOM ELEVATION: 5942.1 FT

Figure A.1 Log of core boring UE20k-1





PROJECT PALANQUIN									
BORING NO. UE20K-3									
LOCATION (NEVADA STATE COORDINATES): N 920,986.92 E 541,499.96									
ANGLE OF BORING Vertical				TYPE OF BORING NX - DIAMOND					
BEARING				DRILLING AGENCY WES					
EL TOP OF HOLE 6190.8 ft - MSL				DEPTH TO WATER TABLE No water encountered					
TOTAL DEPTH 270.5 ft				HOLE STARTED 22 February 1965					
TOTAL CORE RECOVERY				HOLE COMPLETED 1 March 1965					
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	% CORE RECOV. ERY	JOINT DATA FROM CORE LOG				
					REC. PT	STRIKE	DIP	WIDTH & FILLING	
6180.8	0		SANDY SILT, TAN; 1/4 FRAG AND BLURS OF PORPHYRITIC TRACHYTE AND VITROPHYTE						
6170.8	10		? Top of Rock ?						
	20		PORPHYRITIC TRACHYTE, 1/20% WHITE, SUBHEDRAL, EQUIT PHENOCRYSTS OF ALKALI FELDSPAR, (AVERAGES 1/4 IN. IN SIZE), SET IN RED-BRN, POROUS, VERY FINE-GRAINED MATRIX, A FEW SMALL VESICLES. CORE IS BADLY DECOMPOSED AND VERY HIGHLY FRACTURED. CORE BROKEN INTO FRAGMENTS GENERALLY <0.2 FT IN LENGTH. FRAGMENTS OF RED-BRN AND BLACK VITROPHYTE ALSO RECOVERED FROM INTERVAL 10-35 FT.	1.0					
	30			1.5					
	40			5.0					
	50			0.0					
	60			13.0					
6121.6	50								
6110.6	70		Porphyritic trachyte, w/gray-brn, porous matrix. Very highly fractured and decomposed.	4.5					
	80			3.0					
	90			0.0					
	100			5.0					
	110			1.0					
	120			1.1					
	130			1.1					
	140			12.0					
6041.8	150								
	160		PORPHYRITIC TRACHYTE, w/15 TO 20% WHITE, SUBHEDRAL, EQUIT PHENOCRYSTS OF ALKALI FELDSPAR, (AVERAGING 1/4 IN. IN SIZE), SET IN GRAY-BRN, SLIGHTLY POROUS MATRIX. THE CORE IS MODERATELY HIGHLY FRACTURED, w/CORE BROKEN INTO 0.1 TO 1.3 FT SEGMENTS. NUMEROUS 10 TO 10 DEG DIPPING FRACTURES ARE CROSS CUT BY MANY NEAR VERTICAL HAILLINE FRACTURES. FRACTURES ARE HEALED OR PARTIALLY FILLED w/WHITE SILICEOUS MATERIAL AND SPICULARITE	47.9					
	170			30.0					
	180			78.3					
	190			57.3					
	200			26.0					
	210			29.1					
	220			9.0					

(Continued)

PROJECT PALANQUIN									
BORING NO. UE20K-3 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	% CORE RECOV. ERY	JOINT DATA FROM CORE LOG				
					REC. PT	STRIKE	DIP	WIDTH & FILLING	
5980.3	200								
	210			87.0					
	220			95.0					
	230			97.9					
	240			99.0					
	250			89.9					
	260			100.0					
	270			97.9					
5910.3	270			92.0					

BOTTOM DEPTH: 270.5 FT  
BOTTOM ELEVATION: 5910.3 FT-MSL

Figure A.3 Log of core boring UE20k-3

PROJECT PALANQUIN									
BORING NO. UE20K-4									
LOCATION (NEVADA STATE COORDINATES): N 921,272.03 E 541,635.68									
ANGLE OF BORING: Vertical				TYPE OF BORING: RX - DIAMOND					
BEARING:				DRILLING AGENCY: VES					
EL TOP OF HOLE: 6190.5 FT MSL				DEPTH TO WATER TABLE: No water encountered					
TOTAL DEPTH: 199.2 FT				HOLE STARTED: 2 March 1965					
TOTAL CORE RECOVERY: 16.2%				HOLE COMPLETED: 5 March 1965					
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	% CORE RECOV. ERY	WID. FT	STRIKE	DIP	WIDTH & FILLING	
6190.5	0		SANDY SILT, TAN; 1/2" TAG AND SLIPS OF PORPHYRITIC TRACYTE.						
6177.5	10		Top of Rock:						
	20		PORPHYRITIC TRACYTE, 1/20% WHITE, SUBHEDRAL, EQUITANT PHENOCRYSTS OF ALKALI FELDSPAR (1/4 IN. AVERAGE SIZE), SET IN VERY FINE-GRAINED MATRIX, RED-BRN AND POROUS (MAY BE GRN-BRN AND SLIGHTLY POROUS AS SHOWN ON LOG), 5 TO 10% SMALL VESICLES. OCCASIONAL VERY THIN, DK RED- BRN, STEEPLY DIPPING FLOW LAYERS CORE BADLY DECOMPOSED AND VERY HIGHLY FRACTURED 1/2" CORE BROKEN INTO FRAGMENTS FROM 0.1 FT TO 0.6 FT IN LENGTH. FRACTURES COATED 1/2" WHITE SILICEOUS MATE- RIAL AND SPICULARITE.	0.0					* Note: Individual fractures within highly fractured zone - are not represented on log
	30			0.0					
	40			0.0					
	50			27.0					
	60			12.0					
6148.5	60			10.0					
	70			0.0					
	80		Porphyritic trachyte, 1/2" slightly porous to porous, grn-brn matrix very highly fractured.	36.0					
	90			0.0					
	100			16.3					
6081.3	110			5.6					
	120			6.5					
	130			9.0					
	140			13.0					
6043.5	150		Porphyritic trachyte, 1/2" slightly porous to porous, grn-brn matrix very highly fractured.	16.0					
	160			10.0					
6001.3	170			4.0					
	180		PORPHYRITIC TRACYTE, 1/20% WHITE SUBHEDRAL, EQUITANT, PHENOCRYSTS OF ALKALI FELDSPAR (1/4 IN. SIZE SET IN GRN-BRN, H-RD, VERY FINE GRAINED MATRIX, 2 TO 5% SMALL VESICLES. MODERATELY DIPPING THIN DK RED-BRN FLOW LAYERS AND SPHERES LOCALLY PRESENT AS ARE SMALL SPHERULES. CORE IS MODERATELY-HIGHLY FRACTURED. FRACTURES: MOSTLY DIP 20 TO 40 DEG. 1/2" MINOR FILLING OF WHITE SILICEOUS MATERIAL CORE FRAG- MENTS FROM 0.1 FT TO 2.4 FT AVERAGING 0.3 TO 0.6 FT IN LENGTH.	74.0					
	190			20.1					
	199.2			12.2					
5991.3	199.2			15.0					

BOTTOM DEPTH: 199.2 FT  
BOTTOM ELEVATION: 5991.3 FT - MSL.

Figure A.4 Log of core boring UE20k-4

PROJECT PALANQUIN									
BORING NO.: UE20K-5									
LOCATION (NEVADA STATE COORDINATES): N 921,215.44 E 541,555.45									
ANGLE OF BORING: Vertical				TYPE OF BORING: NX - DIAMOND					
BEARING:				DRILLING AGENCY: VES					
EL TOP OF HOLE: 619.4 ft - MSL				DEPTH TO WATER TABLE: No water encountered					
TOTAL DEPTH: 217.7 ft				HOLE STARTED: 5 March 1965					
TOTAL CORE RECOVERY: 27.2%				HOLE COMPLETED: 9 March 1965					
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	% CORE RECOV- ERY	JOINT DATA FROM CORE LOG				WIDTH & FILLING
				MID- PT	STRIKE	DIP			
6191.4	0		SANDY SILT, TAN, w/FRAG AND SCAT- TERED BLINDS OF PORPHYRITIC TRACHYTE						
6181.9	10		Top of Rock						
	20		PORPHYRITIC TRACHYTE, w/20% WHITE, SUBHEDRAL, EQUITANT PHENOCRYSTES OF ALKALI FELDSPAR (AVERAGING 1/4 IN. IN SIZE), SET IN GRAY- BRN (OR RED-BRN) SLIGHTLY POROUS- (POROUS WHERE INDICATED) VERY FINE-GRAINED MATRIX, LOCAL SMALL VESICLES. FLOW STRUCTURE EMPHASIZED BY SMALL IRREGULAR RED-BRN STIRLS AND KENOLITHS. DECOMPOSED AND ALTERED WHERE INDICATED.	17.1					
	30			19.7					
	40			39.0					
	50			0.0					
	52.9		highly fractured, and badly decomposed red-brn matrix from 21.0 ft to 22.5 ft and from 29.2 ft to 30.0 ft.	26.7					
6141.9	50			52.9					
	60			99.0					
	70			92.2					
6135.7	80			100.0					
	90		highly fractured zone w/most of fractures dipping from 0 to 20 deg.	90.0					
6104.4	90			45.6					
	100			18.6					
	110		Porphyritic trachyte, gray-brn, porous decomposed, very highly fractured.	0.0					
	120			1.0					
6065.0	130			0.0					
	140			0.0					
	150			0.0					
	160			3.0					
	170		Porphyritic trachyte, w/red-brn matrix, very porous, badly de- composed, very highly fractured.	13.0					
	180			9.0					
	190			5.0					
	200			3.0					
	210			6.0					

(Continued)

PROJECT PALANQUIN									
BORING NO.: UE20K-5 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	% CORE RECOV- ERY	JOINT DATA FROM CORE LOG				
					MID- PT	STRIKE	DIP	WIDTH & FILLING	
	200								
	210		Porphyritic trachyte, w/red-brn matrix, very porous badly de- composed, very highly fractured.						
5975.7									

BOTTOM DEPTH: 217.7 FT  
BOTTOM ELEVATION: 5975.7 FT - MSL

Figure A.5 Log of core boring UE20k-5

APPENDIX B

PETROGRAPHIC EXAMINATION AND PHYSICAL  
TESTING OF ROCK CORES

## PETROGRAPHIC EXAMINATION AND PHYSICAL TESTING OF ROCK CORES

Four samples were selected for examination from boring UE20k-1. These samples were examined with a stereoscopic microscope on cored, freshly broken, and sawed surfaces. Thin sections of representative areas of each core were prepared and examined with a petrographic microscope. The composition of the feldspar phenocrysts was determined from grain immersion mounts under the petrographic microscope. Representative samples of the groundmass, phenocrysts, and hand-picked mineral grains were prepared and examined on the X-ray diffractometer.

### B.1 PETROGRAPHIC OBSERVATIONS

B.1.1 Sample 1 (Depth 105 feet). The core was a pale red (5R 6/2) to light brownish-gray (5YR 6/1) porphyritic igneous rock containing clear to white subhedral to anhedral feldspar phenocrysts up to 1/2 inch in their longest dimension, and a few smaller ferromagnesian mineral grains, probably pyroxene, that had been altered almost entirely to iron oxide in a very fine-grained groundmass. Many thin, short, irregular cracks were visible on sawed surfaces of the rock. Most of the cracks were lined with iron oxide. Index of refraction measurements and other optical properties indicated that the feldspar phenocrysts were composed of anorthoclase, a soda-rich form of microcline. In thin section, the cryptoperthitic structure of the anorthoclase was evident in almost every phenocryst.

Virtually all the ferromagnesian mineral phenocrysts, pyroxene, and possibly a few olivine crystals were rimmed with iron oxide alteration products. Some crystals were completely altered. Thin sections showed the ground mass of the rock to have a trachytic texture composed of subparallel microlites of alkali feldspar, many extremely small unaltered pyroxene grains, probably augite, and myriads of tiny hematite grains that measured from less than one to five microns in diameter. The reddish color of the rock was due to the presence of the small hematite grains. No quartz was detected either in the thin sections or in the X-ray diffraction pattern of the rock. X-ray patterns indicated that the rock was composed primarily of feldspar, with minor to very minor amounts of pyroxene, hematite, and possibly amphibole. On the basis of its mineralogical composition and texture, the rock was classified as a porphyritic trachyte.<sup>1</sup>

B.1.2 Sample 2 (Depth 214.5 to 215.5 feet). The groundmass of this core had a darker red color than Sample 1, which, as shown in

---

<sup>1</sup> The rock was originally classified as a "trachite porphyry" in this petrographic examination. The term commonly implies an intrusive origin and so is somewhat misleading when applied to the extrusive lava at the Palanquin site. Therefore, the term porphyritic trachyte has been substituted in this appendix to agree with its use elsewhere in the report.

thin sections, was due to a greater abundance of the small hematite crystals. Otherwise the rock was similar to Sample 1, being composed of fresh anorthoclase phenocrysts up to 1/2 inch in diameter and altered ferroan minerals in a very fine-grained trachytic-textured groundmass composed of feldspar microlites, pyroxene, and hematite. The top and bottom surfaces of the core were bounded by high-angle fractures, at least one of which was probably a preexisting joint plane. The core itself contained many short, narrow fractures. The X-ray diffraction pattern of this core was practically identical with that of Sample 1. The core undoubtedly represented another lava flow in which the composition and cooling conditions were very similar to those of Sample 1.

B.1.3 Sample 3 (Depth 306.8 feet). This core was a light gray porphyritic igneous rock, which, except for the absence of the small hematite crystals in the groundmass, had a composition similar to Samples 1 and 2. The rock was composed of large anorthoclase phenocrysts, together with highly altered pyroxene phenocrysts in a very fine-grained, trachytic-textured groundmass. The bottom surface of the core and part of the top surface were preexisting, partially coated joint planes. Examination of sawed surfaces indicated that the rock was highly shattered with short, narrow, unoriented cracks. Many of the ferroan mineral phenocrysts were so completely altered to iron oxide that none of the original crystal structure of the

phenocrysts was preserved. The absence of the small hematite crystals in the groundmass was responsible for the difference in color between this core and Samples 1 and 2. The X-ray diffraction pattern also indicated that the crystalline composition was essentially like that of the other cores.

B.1.4 Sample 4 (Depth 140 feet). This sample consisted of a piece of light gray porphyritic igneous rock core about 4 inches long in which only part of the cored surface was present. The core was obviously from a highly weathered zone. At least three of the irregular surfaces of the core were originally highly weathered fractures. The rock contained several other such fractures. The physical condition of the core was such that it could be broken apart in a person's hands. The fractures were lined with small feldspar crystals, many small highly reflective specular hematite crystals with well-developed crystal faces, and extremely small (less than 10 microns) straw yellow prismatic crystals of an unidentified mineral. All the minerals lining the fractures were secondary, probably a result of hydrothermal alteration. The mass of the rock itself was similar in composition and texture to the other three cores, particularly Sample 3. The anorthoclase phenocrysts appeared fresh and unaltered. Pyroxene phenocrysts were highly altered to iron oxide. The groundmass of feldspar microlites exhibited trachytic texture like the other cores. The tiny hematite crystals present in the groundmass of



Samples 1 and 2 were lacking. X-ray diffraction patterns of this core were similar to patterns of the other three cores.

## B.2 SUMMARY OF PETROGRAPHIC ANALYSIS

Petrographic examination and X-ray diffraction analysis of the four core samples indicated that all had similar mineralogical compositions and textures. The cores were porphyritic igneous rocks, probably from lava flows, consisting of soda-rich feldspar phenocrysts (anorthoclase), and fewer and smaller highly altered mafic phenocrysts (pyroxene and possibly a little olivine) in a dense, very fine-grained matrix composed principally of subparallel feldspar microlites. Rocks of such compositions and textures are classified as porphyritic trachyte. In Samples 1 and 2 the matrix also contained very small, almost submicroscopic hematite grains that imparted a reddish color to the rock. The hematite was not present in the two gray-colored cores. No quartz or clay minerals were detected in any of the cores. All four cores contained many short, narrow cracks, but only Sample 4 was highly weathered and physically weak.

## B.3 CALCULATION OF SPECIFIC GRAVITY

The equations shown below were used in calculating specific gravity.

(1) Bulk dry specific gravity ( $G_o$ ):

$$G_o = \frac{W_o}{V_o D}$$

where

$W_o$  = weight of the oven-dried core, grams

$V_o$  = volume of the core, milliliters, obtained by

(a) measuring core samples from boring UE20k-2, or

(b) measuring water displaced by plastic-sprayed samples from boring UE20k-1

$D$  = density of water at the temperature of the test specimen, grams per milliliter

(2) Saturated surface-dry specific gravity ( $G_m$ ):

$$G_m = \frac{W_s}{W_s - W_w}$$

where

$W_s$  = weight in air of saturated surface-dry core, grams

$W_w$  = weight in water of saturated core, grams

#### B.4 SAMPLE PREPARATION AND UNCONFINED COMPRESSION TESTS

Each sample of 2.12-inch-diameter core was cut to 4.25-inch length with a diamond saw to provide a two-to-one length-diameter ratio. Ends were ground smooth for testing. The load was applied in a testing machine at a uniform rate of 50 psi/sec. Strain was measured with two vertical and two horizontal diametrically opposed SR-4 strain gages, type A3S6. The samples before cutting are illustrated in Figure B.1. The stress-strain curves are shown in Figure B.2.

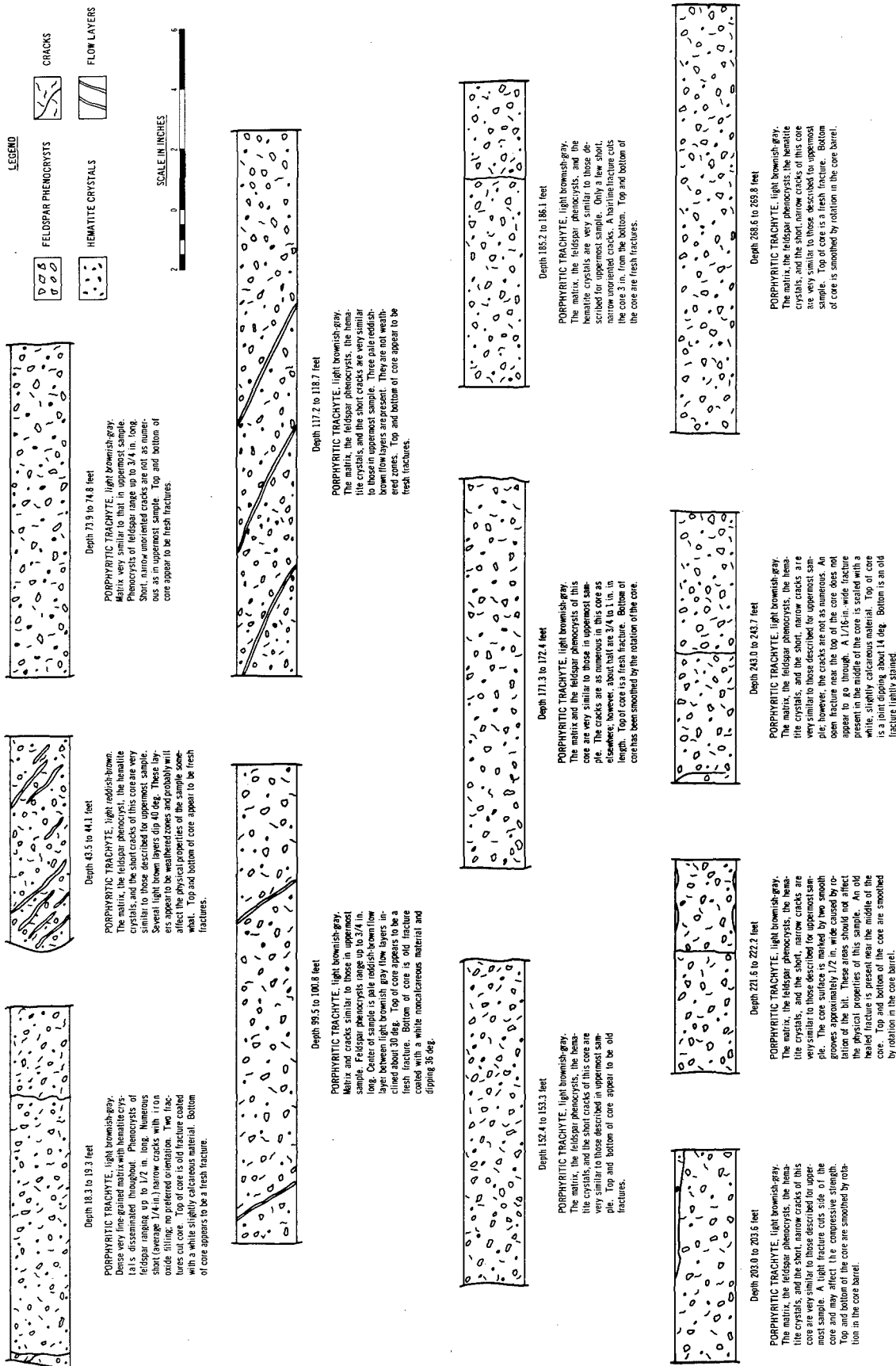


Figure B.1 Description of samples from boring UE20k-2.

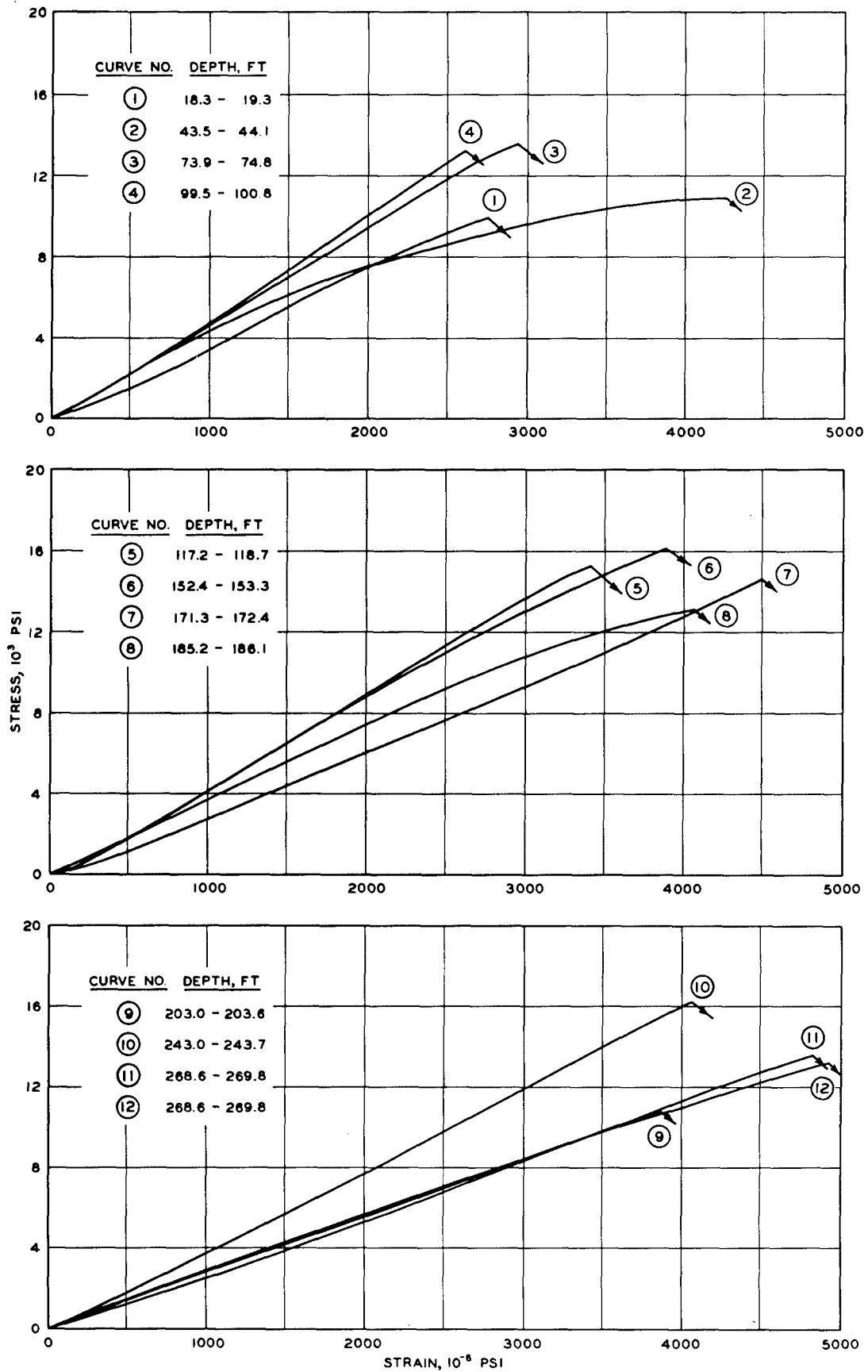


Figure B.2 Stress-strain curves from unconfined compression tests on samples from boring UE20k-2.

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13. ABSTRACT			
<p>A comprehensive geologic and engineering investigation was undertaken at the site on Pahute Mesa selected for the Palanquin event, a cratering experiment conducted in dry rock at the U. S. Atomic Energy Commission's Nevada Test Site. Foundation conditions were determined by means of five borings satellite to the emplacement hole. The site is blanketed by a thin soil cover ranging in thickness from 4 to 13 feet, overlying a 575-foot-thick section of the Ribbon Cliff formation. The uppermost flow of this formation is porphyritic trachyte, which is at least 351 feet thick beneath the site. The Ribbon Cliff formation is immediately underlain by the vitric tuffs and welded tuffs of the Timber Mountain Tuff. Although normally a competent material, the porphyritic trachyte is severely altered and decomposed within zones of intense fracturing related to faulting. Subsurface data indicate the presence of a high-angle normal fault that strikes N27°E and dips 64 degrees to the northwest. Field observations indicate four high-angle joint sets within the Ribbon Cliff formation. Low-angle bedding joints may be present locally. Average physical property values of the porphyritic trachyte are as follows: dry bulk specific gravity, 2.49; dry bulk density, 155 pcf; static unconfined compressive strength, 13,370 psi; modulus of elasticity, <math>3.8 \times 10^6</math> psi; and Poisson's ratio, 0.26. The static unconfined compressive strength tends to increase with increasing density values. There appears to be no major variation of density with depth. Pressure tests indicated that permeability of the media at the Palanquin site was approximately <math>35 \times 10^{-4}</math> cm/sec near the surface and decreased to practically zero at a depth of 110 feet.</p>			

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